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SRB-IIID SOLID ROCKET BOOSTER PERFORMANCE PREDICTION PROGRAM

VOLUME I ENGINEERING DESCRIPTION/USERS INFORMATION MANUAL

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BOOSTER PERFORMANCE PREDICTION PROGRAM.
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Science and Engineering Directorate

Under Contract NAS8-31644

Submitted By:

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**SRB-IIID SOLID ROCKET BOOSTER
PERFORMANCE PREDICTION PROGRAM
VOLUME I - ENGINEERING DESCRIPTION/USERS
INFORMATION MANUAL**

by

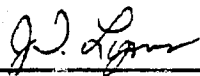
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FOREWORD

This document presents work performed by Northrop Services, Inc., Huntsville, Alabama, while under contract to the Science and Engineering Directorate of Marshall Space Flight Center (NAS8-31644). This task was conducted in response to the requirements of Schedule Order 1.7.5, Amendment No. 1, Task No. 1. Mr. J. R. Redus, EL-24, is the Technical Coordinator.

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Section I

INTRODUCTION

This document is the combined Engineering/Users Manual for the modified Solid Rocket Booster Performance Evaluation Model (SRB-IIID). The SRB-IIID model was developed as an extension to the internal ballistics module (IBM) of the Boeing developed SRB-II performance program. Because of the similarities of the two models, this manual has been prepared to supplement the original Boeing documentation (References 1 and 2). The reader, therefore, is requested to refer to these documents for the understanding of the general program flow.

Part I of this manual contains the engineering description of SRB-IIID which describes the approach used to develop the IIID concept and an explanation of the modifications which were necessary to implement these concepts. Part II of this manual contains program user information and describes the revised options available to the user of the SRB-IIID program.

This document contains Volume I of three volumes, which describe the SRB-IIID model. Volume II contains a sample SRB-IIID prediction case, and Volume III is the programmers manual containing a brief description of some of the major subroutines, a detailed listing of the program and a cross reference of variables used in the SRB-IIID model.

Section II

PART I - SRB-IIID ENGINEERING DESCRIPTION

2.1 SRB-IIID CONCEPT

The motor configuration upon which the SRB-IIID program calculations are based is divided into three sections (see Figure 2-1): the head end section, the cylindrical section and the aft-end section. The geometry of both the head and aft-end sections is modeled exclusively through the use of tables of burn area as a function of burn distance. The grain geometry in the cylindrical section is defined at several planes which are perpendicular to the motor longitudinal axis. These planes are called reference planes and are used to define propellant grain cross-sectional changes along the length of the cylindrical section of a motor. The propellant surface contained between adjacent pairs of reference planes is then assumed to vary in a linear manner.

The cylindrical section is further divided by the program into a number of increments or mass addition regions by the location of increment dividing planes along the longitudinal axis as shown in Figure 2-2. Values of cross-sectional geometry are determined at the increment dividing planes during the burn modeling by linear interpolation between adjacent pairs of reference planes.

The cylindrical section is usually the longest single portion of a motor and the division of this portion in the manner described above provides a more accurate analytical description of the motor being simulated. The use of increment dividing planes to define mass addition regions allows the program to calculate propellant mass generation times as a function of the burning rate which varies along the length of the cylindrical section.

The purpose of developing the SRB-IIID model was to provide the capability of modeling asymmetrical grain conditions which are likely to exist in large solid rocket motors (such as the Space Shuttle SRB), and to be able to predict the effects of these asymmetries on the resulting performance. Examples of the types of asymmetries include initial geometry dispersions caused by such things

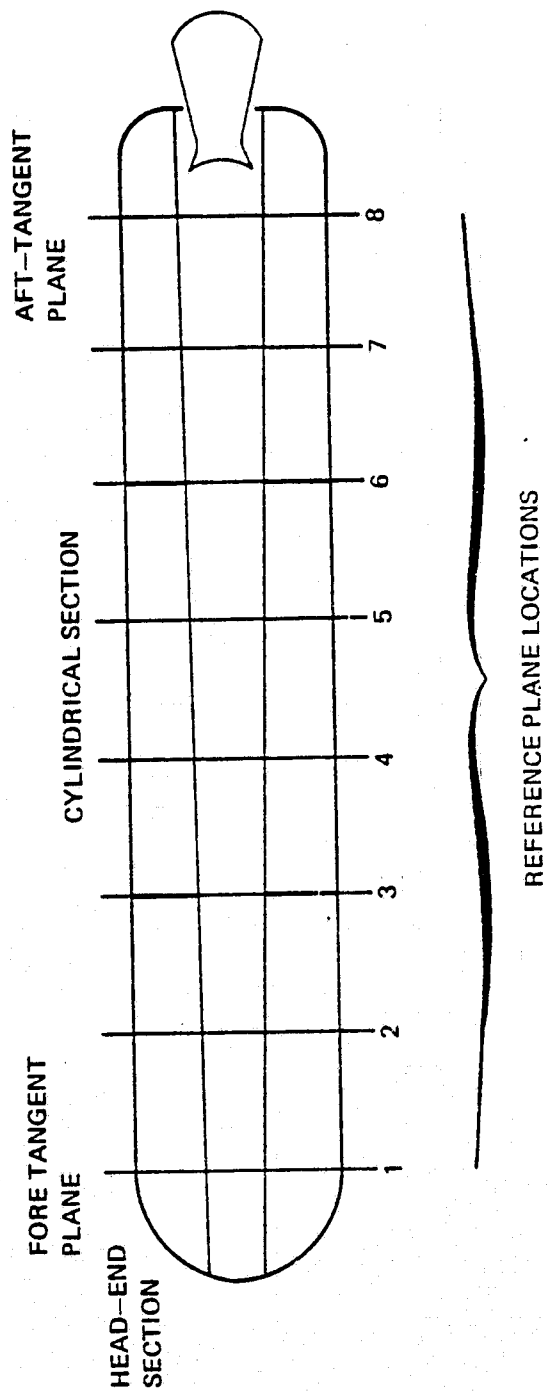


Figure 2-1. MOTOR SIMULATION CONFIGURATION

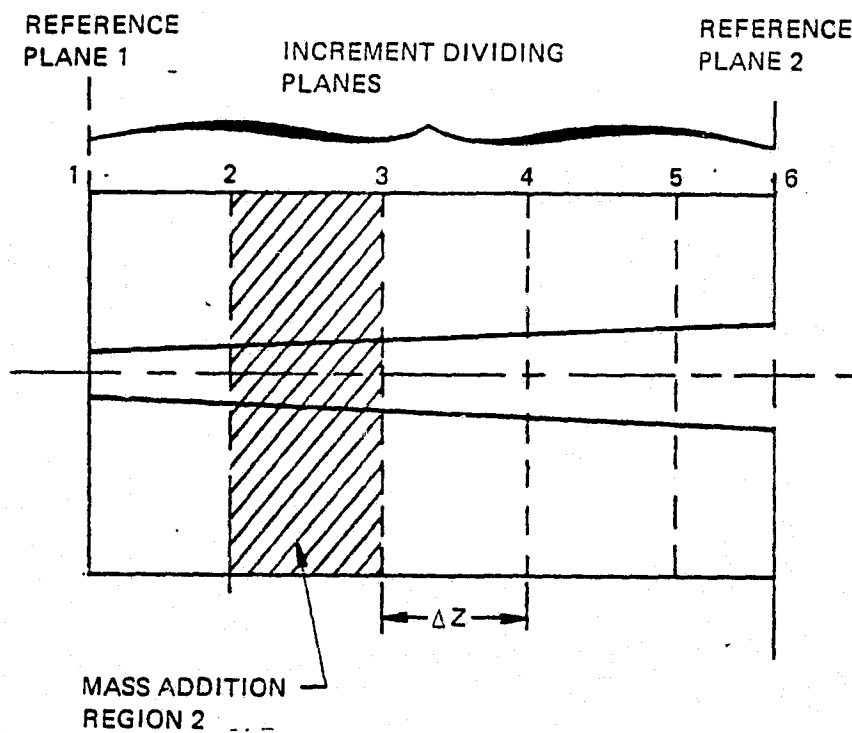


Figure 2-2. INCREMENT DIVIDING PLANE PLACEMENT

as abnormal curing of the grain, mandrel offsets, and so forth; and asymmetrical radial temperature gradients which occur due to a motor's exposure to a particular environment.

The basic method used to model these eccentricities is to further divide the propellant grain in the cylindrical section into circumferential sectors. These sectors are equally spaced subtending angles of $2\pi/n$ (where n is the number of sectors) and the vertex of each sector is on the longitudinal axis of the motor. Each sector is allowed to have discrete local propellant properties which are not necessarily continuous between sectors. Initial sector properties are defined at each input reference plane and are assumed to vary linearly between adjacent reference planes. During the propellant burn modeling, sector properties and their resulting effect on the grain regression are monitored at each reference plane and subsequently at each increment dividing plane.

2.2 SRB-IIID MODELING ASSUMPTIONS

Subsection 2.1 describes how the initial geometry of the motor being simulated is defined for input and subsequently monitored during the burn simulation. Prior to describing the program method of solution, several assumptions which were necessary to translate the physical system into the analytical model contained in SRB-IIID are listed below.

- (1) Propellant burning during ignition and steady-state operation occurs normal to the exposed grain surface.
- (2) The burn rate in the fore and aft head sections is assumed to be constant over the burning surface of the entire region in the two sections respectively.
- (3) Mass addition occurs instantaneously with no velocity component along the motors longitudinal axis.
- (4) Pressure and other thermodynamic properties are constant at any increment dividing plane despite discontinuous sector geometry.
- (5) No burning occurs at discontinuous (circumferential) sector faces.
- (6) The products of combustion obey the perfect gas law.
- (7) The gas flow is one-dimensional and adiabatic.
- (8) For a given cross-section perpendicular to the motor longitudinal axis, the combustion temperature is constant.

- (9) The heat capacity of the combustion gasses is constant.
- (10) The friction forces of the combustion gasses in the port cavity are negligible.

2.3 SRB-IIID METHOD OF SOLUTION

The initial grain geometry within the cylindrical section of the motor is described for each sector by defining sector values at the input reference planes. The program reads these input values along with other propellant variables and end section geometry arrays to start the simulation. The program divides the cylindrical section into a number of increments or mass addition regions by the location of increment dividing planes along the longitudinal axis of the motor as mentioned earlier. These increment dividing planes are automatically placed at each input reference plane and then at specified intervals (ΔZ) down the length of the cylindrical section until either a segment slot face (the gap formed when two grain segments are joined) or the next reference plane is passed. During the time solution of the burn simulation the sector port perimeter and sector port area are determined for each sector of each increment dividing plane by linear interpolation between adjacent reference planes. Mass addition is assumed to occur as a step process calculated on an individual sector basis and then summed to provide the total mass addition between two adjacent increment dividing planes.

The macroscopic flow through the SRB-IIID model is shown in Figure 2-3. The program is broken down into two separate and distinct phases. The first phase is the initialization and input phase, and the second phase is the (time-step) internal ballistic solution.

The functions of the first phase are to read the input data, initialize reference plane/sector geometry and burn rate values, place the increment dividing planes in the manner mentioned above, check for input data errors and print the end section and cylindrical section (sector) initial geometry values.

After phase 1 is completed, the internal ballistic solution is initiated by determining the sector geometry values at each reference plane and the

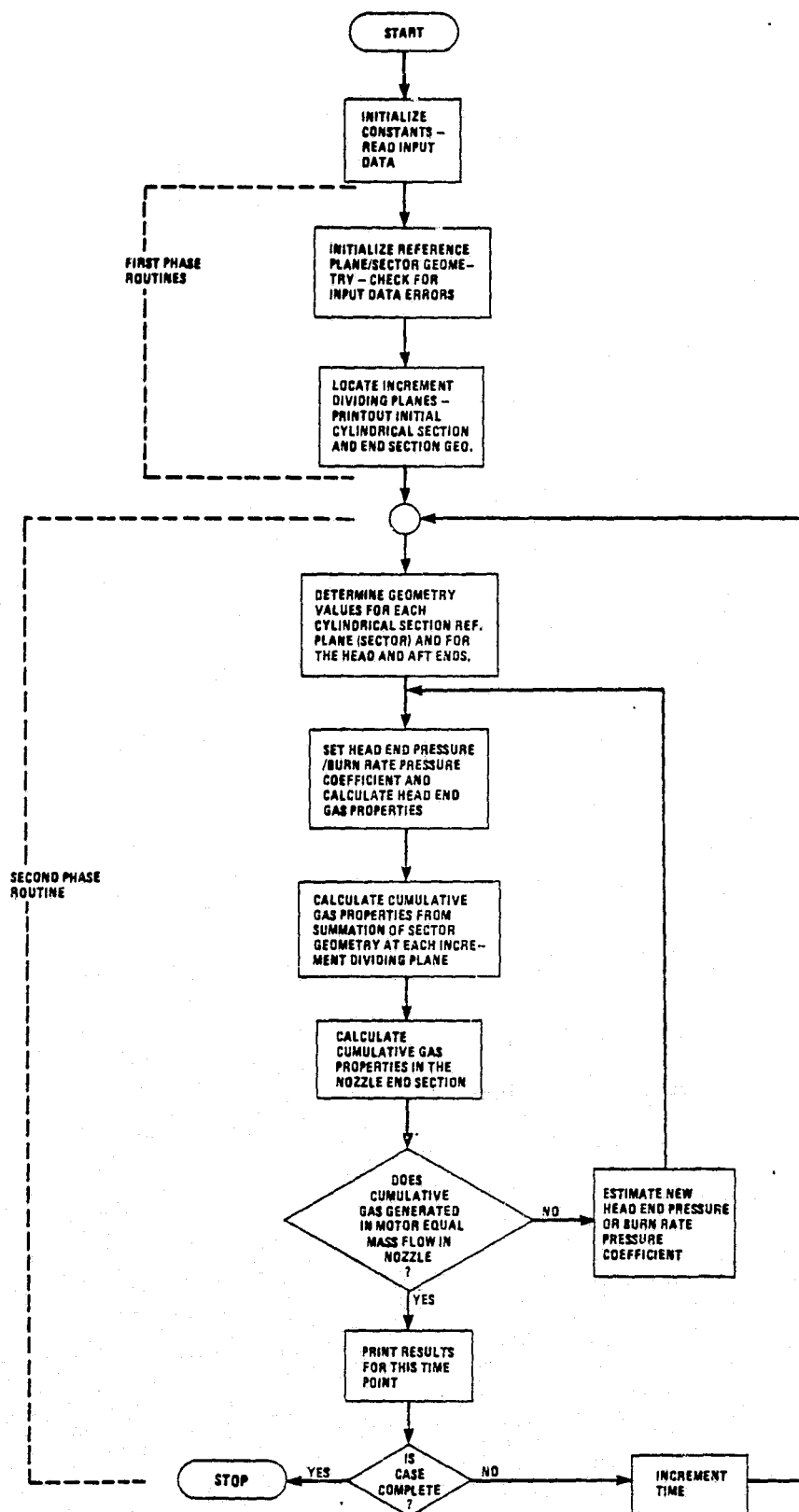


Figure 2-3. SRB-IIID INTERNAL BALLISTICS MACROSCOPIC FLOWCHART

geometry for both end sections using linear interpolation of the input geometry tables (burn area versus distance burned in the end sections and reference plane/sector port perimeter as a function of distance burned in the cylindrical section). The solution proceeds to the calculation of the start transient using input values of head-end pressure as a function of time. An initial estimate of the burn rate pressure coefficient is made, based on the motor configuration parameters and the appropriate (time) value of head-end pressure. This value of the burn rate pressure coefficient is then used in the burn rate law to determine the instantaneous values of mass addition and mass discharge from the head-end section. These values establish the initial thermodynamic conditions for the start of the solution in the cylindrical section.

The solution of the cylindrical section (which is where the IIID modeling concept has been installed) is begun by setting the geometry values in each sector of increment dividing plane 1 equal to the sector values at reference plane 1. Next, a sector burn rate is found as a function of the static pressure at increment dividing plane 1 for each sector being simulated. (The process by which increment dividing plane sector burn rates are established is described in more detail in subsection 2.5 of this manual.)

The values of sector geometry at increment dividing plane 2 are found using linear interpolation between the appropriate sectors of reference planes 1 and 2 (the upstream and downstream reference planes). The increment section mass addition rate is determined for each sector in the mass addition region as a function of sector values of port perimeter at the upstream and downstream increment dividing planes, the increment distance (ΔZ), and the sector burning rate at the upstream adjacent increment dividing plane. Once pertinent variables in each sector being simulated have been calculated in this manner, the resulting sector mass generation rates are summed to produce a total for that mass addition region. (This portion of the solution is done in a similar manner to SRB-II, the only difference is that the calculations are done on a sector basis rather than an entire mass addition region and the sector results are then summed to produce the total for the mass addition region. (Sections 4 and 5 of Reference 3 should be consulted for a more detailed description of the solution within a mass addition region.)

With the total mass generation calculated for the mass addition region, the solving then proceeds to determine the static pressure loss (due to mass generation) and other thermodynamic parameters which are the inlet conditions for the next mass addition region. The sector burn rates for increment dividing plane 2 are then determined, as a function of the static pressure just calculated.

This procedure is then initiated again by interpolating the sector geometry values at the next increment dividing plane and so on until the downstream reference plane is reached. At this point the downstream reference plane becomes the upstream plane and the next reference plane is picked up to continue the solution of the cylindrical section.

Once the solution in the cylindrical section is complete (the aft tangent plane is reached) the same general calculations are performed in the aft-end section, with the exception that a sector solution is not necessary.

Following the solution in the aft end, the flow rate of propellant discharged through the nozzle is computed on the basis of being isentropic (for choked flow) and is then compared with the total propellant discharged from the three sections of motor grain. If these two values do not agree within a specified tolerance, the burn rate pressure coefficient is adjusted and the program returns to the head-end section to solve the entire model over again. This process is repeated until convergence is achieved. Once equilibrium is reached, additional ballistic properties are computed and the motor performance data is printed for the current time point.

Following the motor performance printout the thickness burned during the previous time step in each sector of each increment dividing plane is calculated as a function of the sector burn rates and added to the previous values of sector distance burned. A check is made to determine if a web burnout has occurred during the previous time in any of the sectors being simulated at each of the increment dividing planes. If a burnout has occurred in any sector, a comment is printed which notes the sector number and increment dividing plane location of the burnout.

The time is incremented by the computed time interval and the program returns to begin the next time point solution.

When the start transient has been completed (determined by the last time point in the input head pressure-time history tables), steady flow conditions are assumed and the burn rate pressure coefficient is held constant (with the exception of modification due to radial gradients, see subsection 2.5) while the head-end pressure is iterated upon to seek equilibrium during each time point solution.

This entire process is repeated for each time point solution until any one of the following criteria is met: the chamber pressure is less than or equal to the ambient pressure, the input value of maximum time is reached, or the propellant is totally expended.

2.4 SRB-II PROGRAM MODIFICATIONS

To facilitate the implementation of the SRB-IIID concept into SRB-II several of the broad capabilities contained in SRB-II were removed. The following list shows the general capabilities which were eliminated.

- (1) All theoretical Isp and grain composition calculations
- (2) Lewis thermochemical module
- (3) Anisotropic burn capability
- (4) Inert sliver options
- (5) Reconstruction capability
- (6) All CG and MOI calculations
- (7) Dispersion module
- (8) Thrust scaling module
- (9) Capability to model totally uninhibited slot interfaces
- (10) Capability to model cross sectional shapes other than a circular port in the cylindrical section of the motor.

Once these items and the associated program logic were removed from SRB-II, the next objective was to install the IIID concept in such a way as to leave the remaining program logic unchanged, particularly in the internal

ballistics solution. An example of how this was accomplished was briefly described in the previous subsection pertaining to the SRB-IIID method of solution. This involved the solution of sectors of mass addition regions in the cylindrical section, then summing the sector contributions to determine the mass addition region total mass generation and resulting total port geometry prior to performing the gas dynamic solution of the discharge conditions.

2.5 SRB-IIID THEORETICAL EQUATION MODIFICATION

Two areas of calculation which were contained in the original SRB-II modeling logic were modified specifically for use in the SRB-IIID model. These areas pertained to the method of burn rate calculation and to the manner in which the port volume was calculated for use in the mass addition region gas dynamic solution.

The simplified form of the burn rate law which is used in SRB-II is shown in Equation (1) below. (References 2 and 3 should be consulted for a more detailed development of the burn rate law.)

$$r_b = aP^n \quad (1)$$

where:

r_b is the burn rate

a is the burn rate pressure coefficient

P is the local static pressure

n is the burn rate pressure exponent.

For the purposes of modeling asymmetric radial thermal gradients or grain bulk temperatures which are different from the assumed reference bulk temperature the burn rate pressure coefficient is modified as shown in Equation (2).

$$a' = a \left[e^{\left(\frac{\sigma_p (T_G - T_R)}{P} \right)} \right] \quad (2)$$

where:

a' is the modified burn rate pressure coefficient

a is the original burn rate pressure coefficient

e is the exponential function

σ_p is the pressure coefficient temperature sensitivity factor

T_G is the grain temperature present at the burning face

T_R is the reference bulk temperature upon which σ_p is based.

When thermal gradients are being simulated, the sector burn rate is determined as a function of the temperature (T_G) existing in that sector in addition to the static pressure existing at the particular increment dividing plane. The grain temperature in each sector is determined during the burn simulation as a function of the local sector burn face distance from the case wall.

The calculation of port volume within a mass addition region was modified in SRB-IIID to account for asymmetric radial web burn outs. Prior to a web burn out in any sector of a mass addition region, the sector port volume is calculated as a function of port area at the up and downstream increment dividing planes and the increment length as shown in Equation (3) below:

$$V_1 = \frac{(A_1 + A_2)}{2} * \Delta Z_1 \quad (3)$$

where:

V_1 is the sector port volume

A_1 is the sector port area at the upstream increment dividing plane

A_2 is the sector port area at the downstream increment dividing plane

ΔZ_1 is the increment length

When a web burn out occurs within a sector of a mass addition region, part of the sector between the increment dividing planes which define the mass addition region contains fuel and part of the sector is void of fuel. The ΔZ_1 term in the above equation becomes the length of fuel remaining in the sector mass addition region and a new $\Delta Z'$ is calculated to account for the length within the sector mass addition region which is void of fuel. The new $\Delta Z'$ is the distance from either the upstream increment dividing plane or the downstream plane to the point where the remaining grain intersects the case wall

(see Figure 2-4) depending on the direction from which the burn out occurs. The revised port volume calculation is then as shown in Equation (4) below:

$$V_T = \frac{(A_1 + A_2)}{2} * \Delta Z_1 + A_1 * \Delta Z' + A_2 * \Delta Z' \quad (4)$$

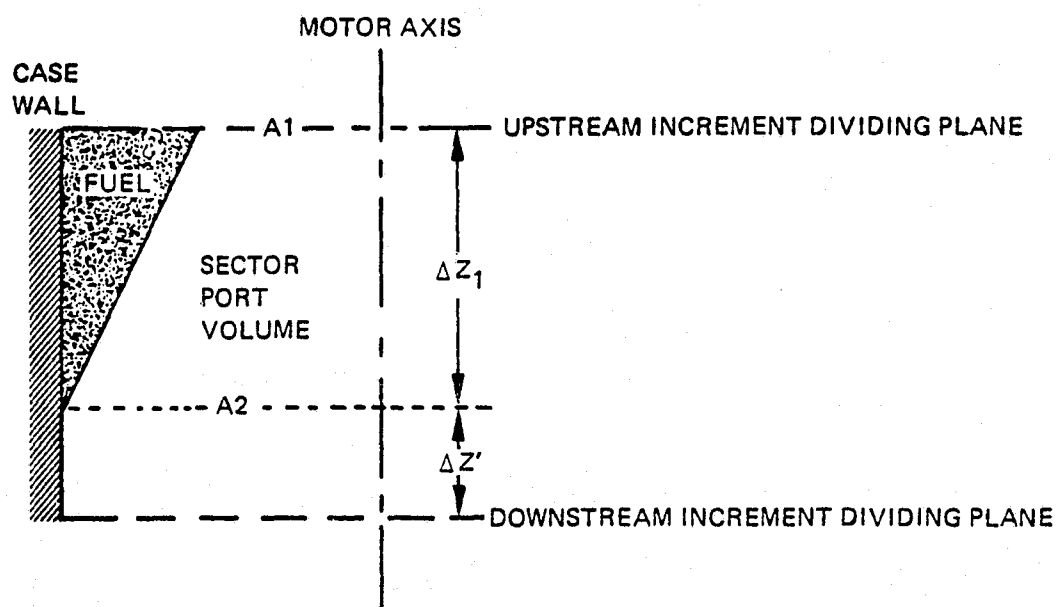
In the above equation one of the last two terms would be zero depending on the direction from which the burn out occurs as shown in Figure 2-4.

2.6 SRB-IIID PROGRAM LIMITATIONS

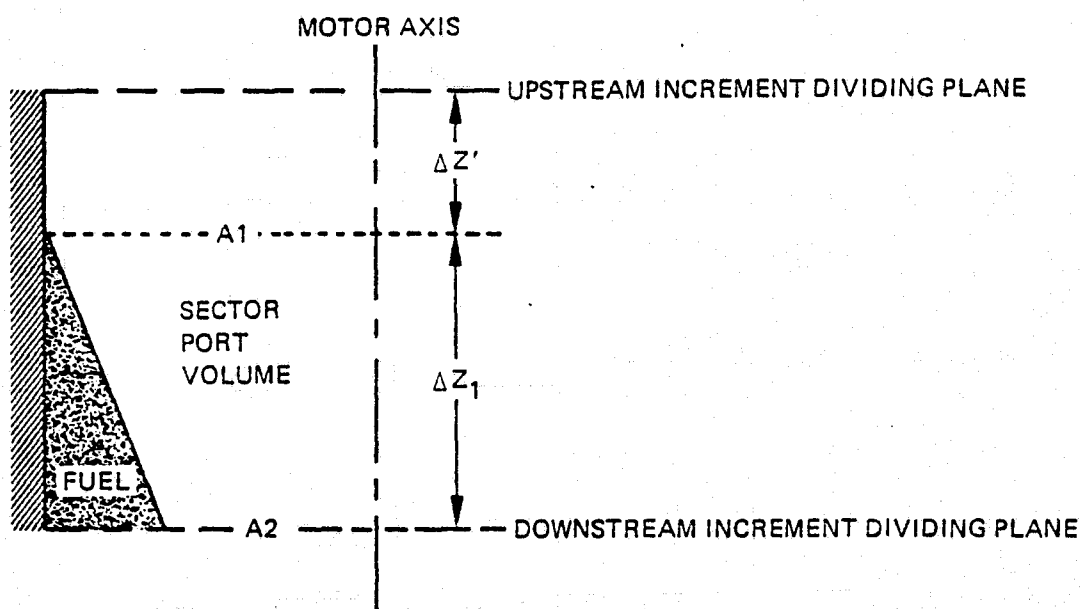
The SRB-IIID program has the following further limitations in addition to those limitations in SRB-II noted in References 1 and 3.

- (1) A maximum of 8 circumferential sectors is used to describe grain asymmetrics.
- (2) Circular port (with minor deviations) is the only cross sectional configuration allowed in the cylindrical section.
- (3) Sector radial gradient inputs are applied equally at all longitudinal locations (no longitudinal variations allowed).
- (4) If more than one sector is being simulated, sector initial geometry must be defined for at least sector I of each input reference plane.
- (5) Circumferential sector divisions do not apply in the head or aft end sections.

The next portion of this manual further describes the SRB-IIID program and provides information necessary to the user of this program.



(a) BURNOUT FROM DOWNSTREAM INCREMENT DIVIDING PLANE



(b) BURNOUT FROM UPSTREAM MOVEMENT DIVIDING PLANE

Figure 2-4. PARTIAL WEB BURNOUT WITHIN A SECTOR OF A MASS ADDITION REGION

Section III

PART II - SRB-IIID USERS INFORMATION

3.1 PROGRAM INPUT DATA

The input data for the SRB-IIID model consist of variables compiled as an integral part of the program (BLOCK DATA) and data input from punched cards. Punched card input is the prime avenue of input and entered under the two separate NAMELIST data packages described below. SRB-IIID requires no set-format input data cards as required by the Lewis thermochemical routines described in Reference 2 since these routines have been eliminated. The IDNOZL data package has also been eliminated from SRB-IIID. The remaining data packages are arranged on cards as shown in Figure 3-1.

3.1.1 Control Data Package

The control data package denoted by a "CONTROL DATA PACKAGE" control card is composed of NAMELIST data under the name INPUT1 and contains integer constants which control the optional outputs such as plot tapes, punched card outputs, and so forth, and a title header card. The variables included under the NAMELIST name INPUT1 are defined in Reference 2.

3.1.2 IBM Data Package

The data necessary to make an internal ballistics prediction are contained under the "IBM DATA PACKAGE" control card and are entered through the NAMELIST name IBDATA. The variables contained in this data package include motor case and propellant grain geometry factors; propellant properties and burning rate model parameters; non-steady flow, steady-state, and program time control parameters; nozzle parameters and geometry table parameters.

The revised inputs under the NAMELIST name IBDATA which were installed for SRB-IIID are shown in Table 3-1. In addition, several inputs which were formerly available for use in SRB-II and which have been eliminated from SRB-IIID are listed in Table 3-2. The definitions of these parameters can be found in the SRB-II Users Manual (Reference 2).

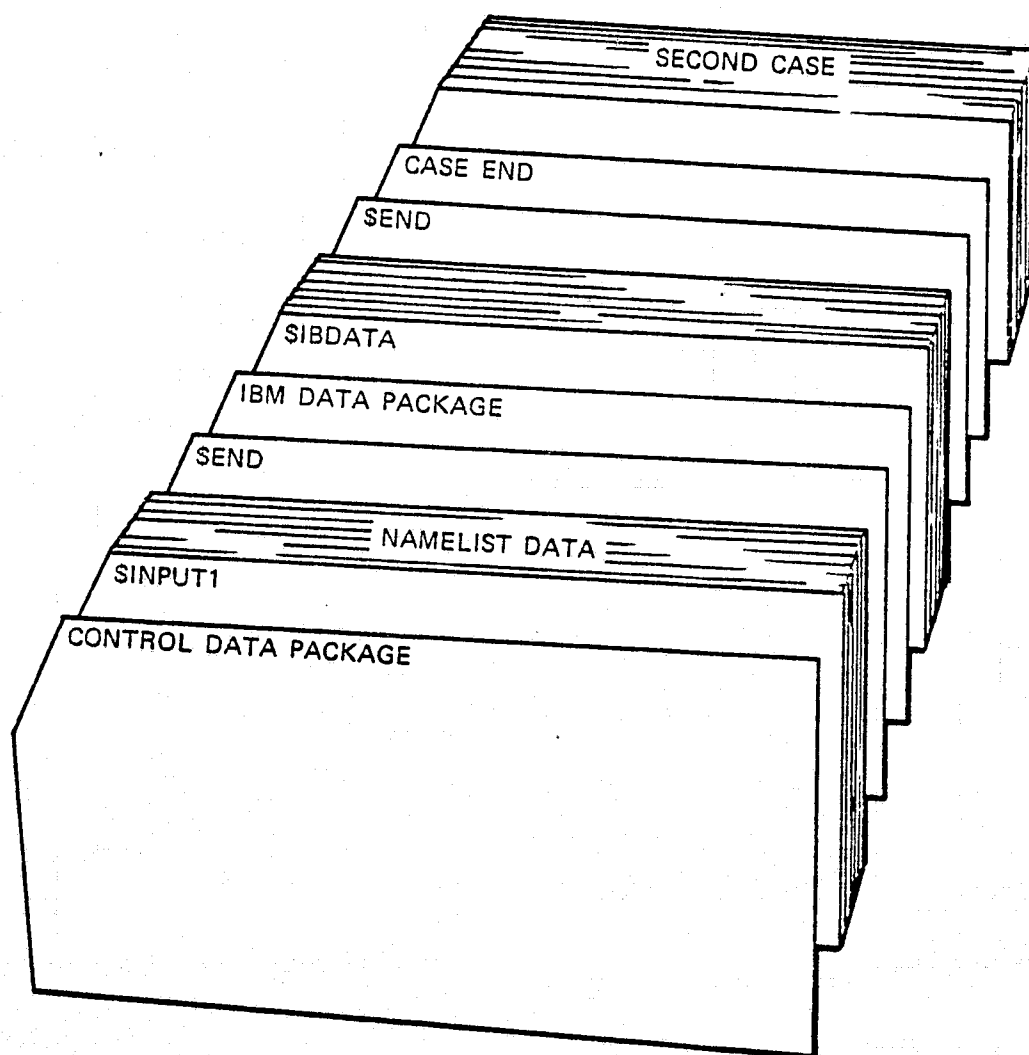


Figure 3-1. INPUT DATA PACKAGE CARD ARRANGEMENT

Table 3-1. SRB-IIID INPUT VARIABLE DEFINITIONS

VARIABLE NAME	DEFINITION
BLKTEM	Grain bulk temperature (°F). Input of this variable > 0 will override any other thermal gradients.
NAKFT	Number of points in the aft end temperature gradient arrays. Maximum allowable = 25. See TEMAFT(I) and TAUFT(I).
NAKHED	Number of points in the head-end temperature gradient arrays (TEMHED(I) and TAUHED(I)). Maximum allowable = 25.
NSCTRS	Number of circumferential sectors being simulated in the cylindrical section. NSCTRS must always be input if greater than 1.
NTAB(IS)	Number of points in the cylindrical section/sector thermal gradient arrays TABI(N,IS) and TABD(N,IS). Dimensional size is (8) and the maximum allowable points per sector is 25.
REFTEM	Grain bulk reference temperature (°F) used in the burn rate law.
RF(IR,IS)	Array of reference plane/sector outer fuel radii (in.) (see Figure 2-2). Dimensional size is (18,8).
RI(IR,IS)	Array of reference plane/sector inner port radii (in.) (see Figure 2-2). Dimensional size is (18,8).
RPL(I,N)	Formerly TAUPL(I,N) in SRB-II. Distance burned in from the initial port interface (in.). The independent array for the reference plane dependent array ALPPL(I,N). Dimensional size is (50,18).
SIGMAP	Burn rate pressure coefficient temperature sensitivity factor (°F ⁻¹). This factor is used to modify the value of the burn rate pressure coefficient whenever a grain temperature different than the reference temperature (REFTEM) is being simulated.
TABD(N,IS)	Sector dependent array of radial temperature gradient data (°F). Dimensional size is (25,8). See NTAB(I) and TABI(N,IS).

Table 3-1. SRB-IIID INPUT VARIABLE DEFINITIONS (Concluded)

VARIABLE NAME	DEFINITION
TABI(N,IS)	Sector independent array of distance from the case wall (in.). See NTAB(I) and TABD(N,IS). Dimensional size is (25,8).
TAUAFT(I)	Distance burned (in) from the port interface in the aft-end. The independent array for the aft-end dependent array TEMAFT(I). See NAKAFT and TEMAFT(I). Dimensional size is (25).
TAUHED(I)	Distance burned (in) from the port interface in the head-end. The independent array for the head-end dependent array TEMHED(I). See NAKHED and TEMHED(I). Dimensional size is (25).
TEMAFT(I)	Dependent array of aft-end temperature gradient data (°F). See NAKAFT and TAUAFT(I). Dimensional size is (25).
TEMHED(I)	Dependent array of head-end temperature gradient data (°F). See NAKHED and TAUHED(I). Dimensional size is (25).

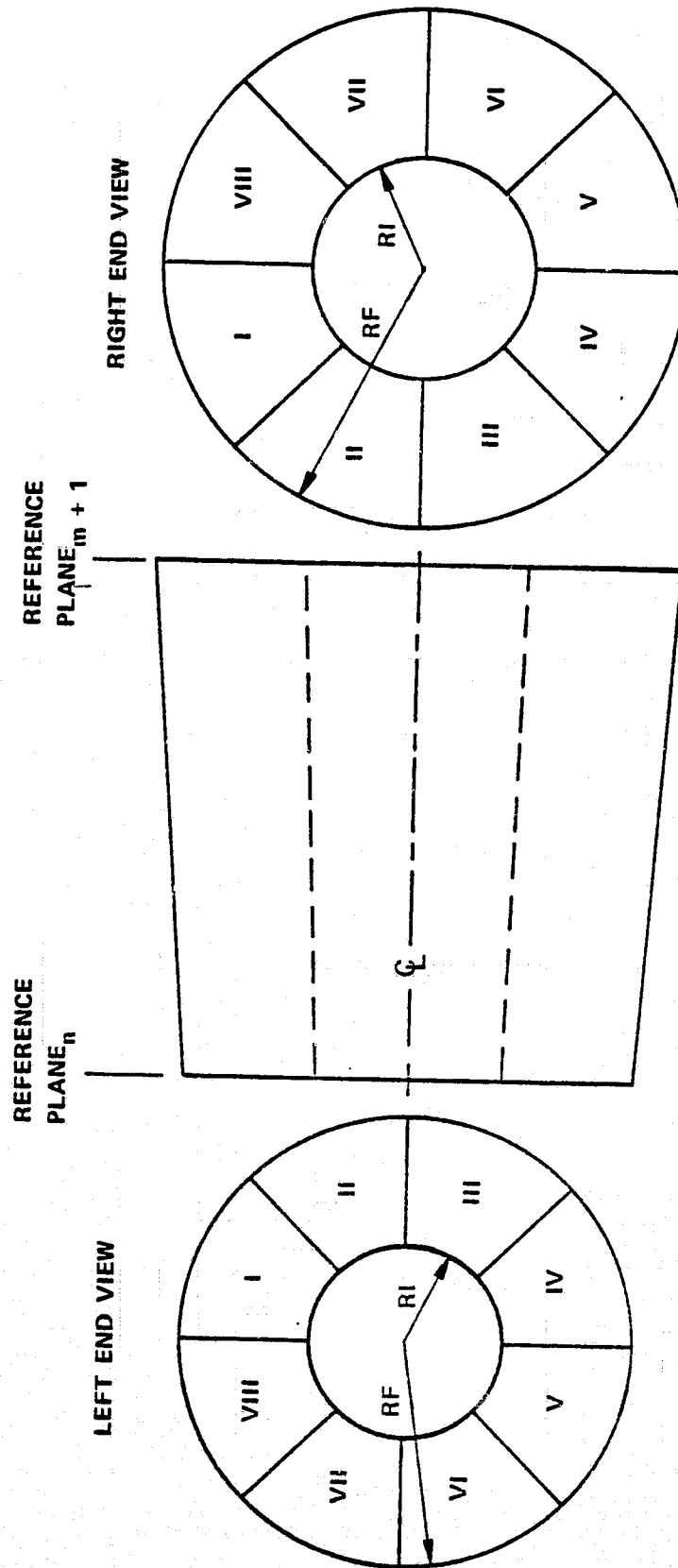


Figure 3-2. SECTOR GEOMETRY DEFINITION

Table 3-2. SRB-II INPUT VARIABLES WHICH HAVE BEEN ELIMINATED IN SRB-IIID

ALS1	ALB	NPUTAB
ALS2	ALE	PMOIHD
TAUW	THO	RMOIHD
A01	TSLVR	XCGHD
A02	DTAU	PMOIN
A03	DTAUW	RMOIN
A04	RIG	XCGN
A05	AK	AKGYP
R2	DRVRF	GEOCON
R3	AKK	PMOINA
R4	AINCPL	PMOINB
R5	RBFLAG	RMOINA
R6	NAKRST	RMOINB
R7	TAUAKR	XCGNA
R8	AKRTAU	XCGNB
ALA	NWRTAB	KMOICG
		GEORUN

3.1.3 SRB-IIID Data Requirements and Options

SRB-IIID has the capability to model from 1 to 8 circumferential sectors in the cylindrical section of the motor. The variable "NSCTRS" must be set to the appropriate value if more than one sector is being simulated. The program assumes that the angle subtended by each sector throughout the entire length of the cylindrical section to be $2\pi/\text{NSCTRS}$. The placement of sector I within a given motor is arbitrary, however, care should be exercised by the user to insure that sector properties which are unique are defined in a consistent manner for each input reference plane.

The variable "RF" and "RI" are the only required sector geometry inputs. Values of these variables must be defined for sector I at all input reference planes, even if the grain configuration being simulated is initially symmetrical. To simplify the amount of required input, only the values of the inner radius (RI) and/or the outer radius (RF) of sectors which are different from the values defined for sector I need be input at the respective reference planes.

The only restriction upon the values of RF and RI is that they are assumed to be measured at the angular mid point of the appropriate sector.

The input variables in SRB-IIID which have been established for asymmetrical radial gradients have been specialized to thermal gradients. For the cylindrical section of a motor, these inputs include TABI, TABD, and NTAB (defined in Table 3-1). In the head-end, a single thermal gradient may be input using the arrays TAUHED and TEMHED. In the aft-end a single gradient may also be input using the independent array TAUAFI together with the dependent array TEMAFT. When thermal gradient cases are desired to be simulated, the variable NAKEND (defined in Reference 2) should be used to include either or both of the end-sections.

SRB-IIID also has the capability to model grain bulk temperatures (as opposed to radial thermal gradients) through the specification of the variable BLKTEM in the input. It should be noted, however, when it is desired to

simulate radial gradients, BLKTEM should be set to 0.0, since it has a preset value of 60°F which will override any thermal gradient data input.

3.2 CURRENT GRAIN DESIGN INPUT DATA

The basic input data required to simulate the latest SRB grain design are stored in an element file on the SRB-IIID program tape number 07994. This method of storing the input data eliminates the need for a large and cumbersome data deck. The data element (CARDZ) contains the basic input data for the Thiokol TC-227A-75 grain design. The compiled listing of this element is shown in Figure 3-3 and should be referred to whenever it is desired to change, modify or add to this data for a particular simulation.

3.3 SRB-IIID SAMPLE PROGRAM RUN DECK

The following is a list of the card deck needed to execute the SRB-IIID program on the Univac 1108 at MSFC. In all cases the @ symbol (7/8 punch) is in card column 1 and blank spaces are denoted by the symbol ∅.

Card 1 @RUN∅SRB3D,1HNTSV453013,URNAMEBINXXX,XX,XXX/XXX
 A B C D E

Card 2 @HDG,P

Card 3 @ASG,T∅SRB3D1,T,07994

Card 4 @FREE∅TPF\$.

Card 5 @ASG,T∅TPF\$. ,F//POS/50

Card 6 @REWIND∅SRB3D1.

Card 7 @COPIN∅SRB3D1.,TPF\$.

Card 8 @FREE∅SRB3D1.

Card 9 @ELT,UL∅CARDZ

Data updates as required for specific run (see Figure 3-3
and the description of card 9 below)

Card 10 @XQT∅PROG

Card 11 @ADD,P∅CARDZ

Card 12 @FIN

```

CARDZ
1 INKLHIN215,TPF(10),CARDZ
2 CONTROL DATA CARDS
3 INPUT
4 TITLE(1)=6HTC-227,6HA-75 6HREVERSE,6HD HEAD,6HEND 6H4/176,6H SRB3D,
5 NSCARD=1,
6 HITOT=7358.,
7 SEND
8 SUB DATA CARDS
9 SUBDATA
10 AINC(1)=0.5,116.761,116.771,143.919,403.048,427.351,427.061,463.204,726.191,
11 746.336,746.346,794.631,854.781,1040.791,1084.171,
12 HCU=1384.171,
13 ANO(1)=15.6.0,
14 RF(1)=
15 72.384,72.384,72.384,72.384,72.314,72.214,72.214,72.214,72.214,72.214,72.214,
16 RF(12)=
17 72.180,72.132,71.344,71.139,
18 RI(1)=
19 28.727,29.110,29.110,28.980,30.750,31.185,31.185,26.950,30.750,31.185,31.185,
20 RI(12)=
21 30.910,31.567,40.320,41.680,
22 SA(1)=116.761,427.051,746.336,
23 SB(1)=116.771,427.061,746.346,
24 DELZ=15.,
25 HHR=20.14,
26 SLTDRN(1)=3.3.0,
27 KPLANE=15,
28 DH=1.,
29 AOH=90.,
30 BTAE=0.0,
31 DH=1.,
32 UN=1.,
33 UN=90.,
34 AOH=90.,
35 DLHF=0.01,
36 AKU(1)=500.,
37 AKR(2)=C-03783,0.35,
38 AKH(3)=C-03783,0.35,
39 KEFTEN=0.0,
40 BLATEH=0.0,
41 STGMAP=C-030975,
42 AKSLOT(1)=0.03783,0.35,
43 SLTDRN(1)=3.3.,
44 DELF=C-036345,
45 CM=0.9595,
46 DELH=22.81,
47 ERBAR=C-0078,
48 ENEXP=0.86,
49 PUNBAR=634.,
50 PA=14.778,
51 TAUNNA=29.46,
52 TAUNNB=20.67,
53 HSUBMG=27.854,
54 FCOR=-3335.,

```

Figure 3-3. COMPILER LISTING OF INPUT DATA ELEMENT CARDZ

CARDZ

```

54  *PH=5,
55  *HST(1)=14.77,405.812.848.863.
56  *THEPH(1)=0.0,0.25,0.50,0.75,1.0,
57  *N=55,35,
58  *CSTR=7,
59  *PRESS(1)=0.20,0.40,0.60,0.80,1.00,0.20,0.
60  *TCOMB(1)=597.5984.6054.6116.6163.26191.
61  *ANW(1)=27.96,28.096,28.217,28.322,28.404,28.458,
62  *GAWAG(1)=1.15914,1.15933,1.15953,1.15972,1.15992,2.01.16011,
63  *CSIR(1)=5072.2,5089.9,5104.7,5116.6,5125.6,2.5131.6,
64  *STFLAG=1,
65  *DELST=0.25,
66  *DELTS=2.0,
67  *PHISS=2.0,
68  *ULLTTO=0.50,
69  *PHITTO=0.5,
70  *TIMAX=127.
71  *I=1,
72  *ANITM=2.0,
73  *ANZ=17.9,
74  *THETEX=11.2,
75  *DE=145.645,
76  *UT=54.43,
77  *NCONT=1,
78  *PRIFLG=1,
79  *PHI=29.556,
80  *NSUBHC=1,
81  *TA(1)=2538.13514.4547.5637.6783.7985.9245.2810473.
82  *TAZB(1)=853.1787.2826.3884.5034.6240.7417.28666.
83  *TAUNB(1)=0.3,0.6,0.9,1.2,1.5,1.8,2.0,2.8,5.0,
84  *TRSUB(1)=41.5,43.8,44.6,48.6,48.6,45.0,48.0,
85  *TXSUB(1)=0.0,1.0,3.0,22.0,40.0,40.5,44.72,
86  *NPSUB=7,
87  *HPA=33,
88  *TIMEPA(1)=0.0,4.8,12.16,20.24,32.36,40.44,48.52,56.60,64.68,
89  *68.72,76.80,84.88,92.96,100.104,108.112,116.120,124.128,
90  *1000,
91  *TBLPA(1)=14.778,14.708,14.493,14.132,13.625,12.972,12.194,11.366,10.326,
92  *9.306,8.271,7.243,6.264,5.34,4.5,3.36,3.049,2.451,1.944,1.521,1.174,
93  *0.903,0.681,0.507,0.375,0.278,0.201,0.146,0.104,0.076,0.056,0.035,
94  *NGEUND=50,
95  *TAUHD(1)=
96  *000000,
97  *500000+01,
98  *800000+01,
99  *1000000+02,
100 *1281000+02,
101 *1600000+02,
102 *1812000+02,
103 *2000000+02,
104 *3000000+02,
105 *4000000+02,
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723 *9810000+01,
724 *1200000+02,
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726 *1800000+02,
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736 *8500000+01,
737 *9810000+01,
738 *1200000+02,
739 *1500000+02,
740 *1800000+02,
741 *1964800+02,
742 *2400000+02,
743 *3800000+02,
744 *4365700+02,
745 *1992819+06,
746 *1996675+06,
747 *1997799+06,
748 *1962201+06,
749 *4000000+01,
750 *8500000+01,
751 *9810000+01,
752 *1200000+02,
753 *1500000+02,
754 *1800000+02,
755 *1964800+02,
756 *2400000+02,
757 *3800000+02,
758 *4365700+02,
759 *1992819+06,
760 *1996675+06,
761 *1997799+06,
762 *1962201+06,
763 *4000000+01,
764 *8500000+01,
765 *9810000+01,
766 *1200000+02,
767 *1500000+02,
768 *1800000+02,
769 *1964800+02,
770 *2400000+02,
771 *3800000+02,
772 *4365700+02,
773 *1992819+06,
774 *1996675+06,
775 *1997799+06,
776 *1962201+06,
777 *4000000+01,
778 *8500000+01,
779 *9810000+01,
780 *1200000+02,
781 *1500000+02,
782 *1800000+02,
783 *1964800+02,
784 *2400000+02,
785 *3800000+02,
786 *4365700+02,
787 *1992819+0
```

100	1925525+36.	1892787+66.	185025+36.	1807487+36.	1766137+36.
101	1719924+36.	1704647+36.	1551024+36.	1457076+36.	1439715+36.
102	1435634+36.	1268935+36.	1123861+36.	11122951+36.	1096236+36.
103	9819881+35.	9551628+35.	8141196+35.	7365291+35.	6738955+35.
104	5368681+35.	4348506+35.	4127281+35.	3281297+35.	3104130+35.
105	2565551+35.	2312928+35.	1844226+35.	1818823+35.	1812474+35.
106	17928915+35.	17271091+35.	15551291+35.	14270241+35.	13251359+35.
107	11729036+35.	10348896+35.	90286500+34.	75671199+34.	60107009+34.
108	44498825+34.	2886650+34.	36115848+33.	76293345+35.	50000.
109	NGEOMH=22.				
110	TAUN(1)=2..2..4..6..8..10..12..14..16..17..18..19..20..20.670.21..22..23..24..				
111	26..28..29..46..50..				
112	ABNA(1)=9279..9628..9979..10351..10656..10988..11397..11799..12088..12239..				
113	12389..12559..12729..12450..10500..6649..5505..464..2892..1148..200.0.				
114	ABNB(1)=14209..14696..14768..14487..13964..13263..12289..11300..9726..8650..				
115	7390..5530..3050..9330.				
116	VCHNP=3362642.14.				
117	VCNINP=1043420..				
118	VCNINA=441501..				
119	VCNINB=599419..				
120	VFN0=2831295.1.				
121	VFN0=505126.1				
122	VFN0A=264736.1				
123	VFN0B=240390..				
124	NGE0(1)=32.	24.			
125	NGE0(3)=24.				
126	NGE0(4)=24.				
127	NGE0(5)=23.				
128	NGE0(6)=23.				
129	NGE0(7)=24.				
130	NGE0(8)=24.				
131	NGE0(9)=23.				
132	NGE0(10)=23.				
133	NGE0(11)=23.				
134	NGE0(12)=23.				
135	NGE0(13)=23.				
136	NGE0(14)=18.				
137	NGE0(15)=19.				
138	APORT(1)=				
139					
140					
141					
142					
143					
144					
145					
146					
147					
148					
149					
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151					
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160					
161					

Figure 3-3. -COMPILER LISTING OF INPUT DATA ELEMENT CARDZ (Continued)

CARDZ

```

162 C-18290E 03, 0-19547E 03, 0-20004E 03, 0-22200E 03, 0-23317E 03, 0-24574E 03,
163 0-25830E 03, 0-27007E 03, 0-28343E 03, 0-29600E 03, 0-30857E 03, 0-32113E 03,
164 0-33370E 03, 0-34627E 03, 0-35883E 03, 0-37140E 03, 0-38397E 03, 0-39653E 03,
165 0-40910E 03, 0-42166E 03, 0-43423E 03, 0-44680E 03, 0-45937E 03, 0-47193E 03,
166 0-48450E 03, 0-49706E 03, 0-50963E 03, 0-52220E 03, 0-53477E 03, 0-54734E 03,
167 0-55991E 03, 0-57247E 03, 0-58504E 03, 0-59761E 03, 0-61018E 03, 0-62275E 03,
168 0-63532E 03, 0-64789E 03, 0-66046E 03, 0-67303E 03, 0-68560E 03, 0-69817E 03,
169 0-71074E 03, 0-72331E 03, 0-73588E 03, 0-74845E 03, 0-76102E 03, 0-77359E 03,
170 0-78616E 03, 0-79873E 03, 0-81130E 03, 0-82387E 03, 0-83644E 03, 0-84901E 03,
171 0-86158E 03, 0-87415E 03, 0-88672E 03, 0-89929E 03, 0-91186E 03, 0-92443E 03,
172 0-93700E 03, 0-94957E 03, 0-96214E 03, 0-97471E 03, 0-98728E 03, 0-100000E 03,
173 0-101257E 03, 0-102514E 03, 0-103771E 03, 0-105028E 03, 0-106285E 03, 0-107542E 03,
174 0-108799E 03, 0-110056E 03, 0-111313E 03, 0-112570E 03, 0-113827E 03, 0-115084E 03,
175 0-116341E 03, 0-117598E 03, 0-118855E 03, 0-120112E 03, 0-121369E 03, 0-122626E 03,
176 0-123883E 03, 0-125140E 03, 0-126397E 03, 0-127654E 03, 0-128911E 03, 0-130168E 03,
177 0-131425E 03, 0-132682E 03, 0-133939E 03, 0-135196E 03, 0-136453E 03, 0-137710E 03,
178 0-138967E 03, 0-140224E 03, 0-141481E 03, 0-142738E 03, 0-143995E 03, 0-145252E 03,
179 0-146509E 03, 0-147766E 03, 0-149023E 03, 0-150280E 03, 0-151537E 03, 0-152794E 03,
180 0-154051E 03, 0-155308E 03, 0-156565E 03, 0-157822E 03, 0-159079E 03, 0-160336E 03,
181 0-161593E 03, 0-162850E 03, 0-164107E 03, 0-165364E 03, 0-166621E 03, 0-167878E 03,
182 0-169135E 03, 0-170392E 03, 0-171649E 03, 0-172906E 03, 0-174163E 03, 0-175420E 03,
183 0-176677E 03, 0-177934E 03, 0-179191E 03, 0-180448E 03, 0-181705E 03, 0-182962E 03,
184 0-184219E 03, 0-185476E 03, 0-186733E 03, 0-187990E 03, 0-189247E 03, 0-190504E 03,
185 0-191761E 03, 0-193018E 03, 0-194275E 03, 0-195532E 03, 0-196789E 03, 0-198046E 03,
186 0-199303E 03, 0-200560E 03, 0-201817E 03, 0-203074E 03, 0-204331E 03, 0-205588E 03,
187 0-206845E 03, 0-208102E 03, 0-209359E 03, 0-210616E 03, 0-211873E 03, 0-213130E 03,
188 0-214387E 03, 0-215644E 03, 0-216901E 03, 0-218158E 03, 0-219415E 03, 0-220672E 03,
189 0-221929E 03, 0-223186E 03, 0-224443E 03, 0-225700E 03, 0-226957E 03, 0-228214E 03,
190 0-229471E 03, 0-230728E 03, 0-231985E 03, 0-233242E 03, 0-234499E 03, 0-235756E 03,
191 0-237013E 03, 0-238270E 03, 0-239527E 03, 0-240784E 03, 0-242041E 03, 0-243298E 03,
192 0-244555E 03, 0-245812E 03, 0-247069E 03, 0-248326E 03, 0-249583E 03, 0-250840E 03,
193 0-252097E 03, 0-253354E 03, 0-254611E 03, 0-255868E 03, 0-257125E 03, 0-258382E 03,
194 0-259639E 03, 0-260896E 03, 0-262153E 03, 0-263410E 03, 0-264667E 03, 0-265924E 03,
195 0-267181E 03, 0-268438E 03, 0-269695E 03, 0-270952E 03, 0-272209E 03, 0-273466E 03,
196 0-274723E 03, 0-275980E 03, 0-277237E 03, 0-278494E 03, 0-279751E 03, 0-281008E 03,
197 0-282265E 03, 0-283522E 03, 0-284779E 03, 0-286036E 03, 0-287293E 03, 0-288550E 03,
198 0-289807E 03, 0-291064E 03, 0-292321E 03, 0-293578E 03, 0-294835E 03, 0-296092E 03,
199 0-297349E 03, 0-298606E 03, 0-299863E 03, 0-301120E 03, 0-302377E 03, 0-303634E 03,
200 0-304891E 03, 0-306148E 03, 0-307405E 03, 0-308662E 03, 0-309919E 03, 0-311176E 03,
201 0-312433E 03, 0-313690E 03, 0-314947E 03, 0-316204E 03, 0-317461E 03, 0-318718E 03,
202 0-319975E 03, 0-321232E 03, 0-322489E 03, 0-323746E 03, 0-325003E 03, 0-326260E 03,
203 0-327517E 03, 0-328774E 03, 0-330031E 03, 0-331288E 03, 0-332545E 03, 0-333802E 03,
204 0-335059E 03, 0-336316E 03, 0-337573E 03, 0-338830E 03, 0-340087E 03, 0-341344E 03,
205 0-342601E 03, 0-343858E 03, 0-345115E 03, 0-346372E 03, 0-347629E 03, 0-348886E 03,
206 0-350143E 03, 0-351400E 03, 0-352657E 03, 0-353914E 03, 0-355171E 03, 0-356428E 03,
207 0-357685E 03, 0-358942E 03, 0-360199E 03, 0-361456E 03, 0-362713E 03, 0-363970E 03,
208 0-365227E 03, 0-366484E 03, 0-367741E 03, 0-368998E 03, 0-370255E 03, 0-371512E 03,
209 0-372769E 03, 0-374026E 03, 0-375283E 03, 0-376540E 03, 0-377797E 03, 0-379054E 03,
210 0-380311E 03, 0-381568E 03, 0-382825E 03, 0-384082E 03, 0-385339E 03, 0-386596E 03,
211 0-387853E 03, 0-389110E 03, 0-390367E 03, 0-391624E 03, 0-392881E 03, 0-394138E 03,
212 0-395395E 03, 0-396652E 03, 0-397909E 03, 0-399166E 03, 0-400423E 03, 0-401680E 03,
213 0-402937E 03, 0-404194E 03, 0-405451E 03, 0-406708E 03, 0-407965E 03, 0-409222E 03,
214 0-410479E 03, 0-411736E 03, 0-412993E 03, 0-414250E 03, 0-415507E 03, 0-416764E 03,
215 0-418021E 03, 0-419278E 03, 0-420535E 03, 0-421792E 03, 0-423049E 03, 0-424306E 03,

```

Figure 3-3. COMPILER LISTING OF INPUT DATA ELEMENT CARDZ (Continued)

CARDZ

```

216 MPL(1,10)= , 0.20000E 01, 0.40000E 01, 0.60000E 01, 0.80000E 01, 0.10000E 02,
217 0.14000E 02, 0.18000E 02, 0.22000E 02, 0.26000E 02, 0.30000E 02,
218 0.34000E 02, 0.38000E 02, 0.42000E 02, 0.46000E 02, 0.50000E 02,
219 0.54000E 02, 0.58000E 02, 0.62000E 02, 0.66000E 02, 0.70000E 02,
220 0.74000E 02, 0.78000E 02, 0.82000E 02, 0.86000E 02, 0.90000E 02,
221 ALPPL(1,10)=
222 0.19594E 03, 0.20851E 03, 0.22107E 03, 0.23364E 03, 0.24621E 03, 0.25877E 03,
223 0.27134E 03, 0.28391E 03, 0.29647E 03, 0.30904E 03, 0.32160E 03, 0.33417E 03,
224 0.34674E 03, 0.35930E 03, 0.37187E 03, 0.38444E 03, 0.39700E 03, 0.40957E 03,
225 0.42214E 03, 0.43470E 03, 0.44727E 03, 0.45984E 03, 0.47240E 03, 0.48497E 03,
226 0.49754E 03, 0.51010E 03, 0.52267E 03, 0.53524E 03, 0.54780E 03, 0.56037E 03,
227 0.57294E 03, 0.58550E 03, 0.59807E 03, 0.61064E 03, 0.62320E 03, 0.63577E 03,
228 0.64834E 03, 0.66090E 03, 0.67347E 03, 0.68604E 03, 0.69860E 03, 0.71117E 03,
229 0.72374E 03, 0.73630E 03, 0.74887E 03, 0.76144E 03, 0.77400E 03, 0.78657E 03,
230 0.79914E 03, 0.81170E 03, 0.82427E 03, 0.83684E 03, 0.84940E 03, 0.86197E 03,
231 0.87454E 03, 0.88710E 03, 0.89967E 03, 0.91224E 03, 0.92480E 03, 0.93737E 03,
232 0.94994E 03, 0.96250E 03, 0.97507E 03, 0.98764E 03, 1.00020E 03, 1.01277E 03,
233 1.02534E 03, 1.03790E 03, 1.05047E 03, 1.06304E 03, 1.07560E 03, 1.08817E 03,
234 1.10074E 03, 1.11330E 03, 1.12587E 03, 1.13844E 03, 1.15100E 03, 1.16357E 03,
235 1.17614E 03, 1.18870E 03, 1.20127E 03, 1.21384E 03, 1.22640E 03, 1.23897E 03,
236 1.25154E 03, 1.26410E 03, 1.27667E 03, 1.28924E 03, 1.30180E 03, 1.31437E 03,
237 1.32694E 03, 1.33950E 03, 1.35207E 03, 1.36464E 03, 1.37720E 03, 1.38977E 03,
238 1.40234E 03, 1.41490E 03, 1.42747E 03, 1.44004E 03, 1.45260E 03, 1.46517E 03,
239 1.47774E 03, 1.49030E 03, 1.50287E 03, 1.51544E 03, 1.52800E 03, 1.54057E 03,
240 1.55314E 03, 1.56570E 03, 1.57827E 03, 1.59084E 03, 1.60340E 03, 1.61597E 03,
241 1.62854E 03, 1.64110E 03, 1.65367E 03, 1.66624E 03, 1.67880E 03, 1.69137E 03,
242 1.70394E 03, 1.71650E 03, 1.72907E 03, 1.74164E 03, 1.75420E 03, 1.76677E 03,
243 1.77934E 03, 1.79190E 03, 1.80447E 03, 1.81704E 03, 1.82960E 03, 1.84217E 03,
244 1.85474E 03, 1.86730E 03, 1.87987E 03, 1.89244E 03, 1.90500E 03, 1.91757E 03,
245 1.93014E 03, 1.94270E 03, 1.95527E 03, 1.96784E 03, 1.98040E 03, 1.99297E 03,
246 2.00554E 03, 2.01810E 03, 2.03067E 03, 2.04324E 03, 2.05580E 03, 2.06837E 03,
247 2.08094E 03, 2.09350E 03, 2.10607E 03, 2.11864E 03, 2.13120E 03, 2.14377E 03,
248 2.15634E 03, 2.16890E 03, 2.18147E 03, 2.19404E 03, 2.20660E 03, 2.21917E 03,
249 2.23174E 03, 2.24430E 03, 2.25687E 03, 2.26944E 03, 2.28200E 03, 2.29457E 03,
250 2.30714E 03, 2.31970E 03, 2.33227E 03, 2.34484E 03, 2.35740E 03, 2.36997E 03,
251 2.38254E 03, 2.39510E 03, 2.40767E 03, 2.42024E 03, 2.43280E 03, 2.44537E 03,
252 2.45794E 03, 2.47050E 03, 2.48307E 03, 2.49564E 03, 2.50820E 03, 2.52077E 03,
253 2.53334E 03, 2.54590E 03, 2.55847E 03, 2.57104E 03, 2.58360E 03, 2.59617E 03,
254 2.60874E 03, 2.62130E 03, 2.63387E 03, 2.64644E 03, 2.65900E 03, 2.67157E 03,
255 2.68414E 03, 2.69670E 03, 2.70927E 03, 2.72184E 03, 2.73440E 03, 2.74697E 03,
256 2.75954E 03, 2.77210E 03, 2.78467E 03, 2.79724E 03, 2.80980E 03, 2.82237E 03,
257 2.83494E 03, 2.84750E 03, 2.86007E 03, 2.87264E 03, 2.88520E 03, 2.89777E 03,
258 2.91034E 03, 2.92290E 03, 2.93547E 03, 2.94804E 03, 2.96060E 03, 2.97317E 03,
259 2.98574E 03, 2.99830E 03, 3.01087E 03, 3.02344E 03, 3.03600E 03, 3.04857E 03,
260 3.06114E 03, 3.07370E 03, 3.08627E 03, 3.09884E 03, 3.11140E 03, 3.12397E 03,
261 3.13654E 03, 3.14910E 03, 3.16167E 03, 3.17424E 03, 3.18680E 03, 3.19937E 03,
262 3.21194E 03, 3.22450E 03, 3.23707E 03, 3.24964E 03, 3.26220E 03, 3.27477E 03,
263 3.28734E 03, 3.29990E 03, 3.31247E 03, 3.32504E 03, 3.33760E 03, 3.35017E 03,
264 3.36274E 03, 3.37530E 03, 3.38787E 03, 3.40044E 03, 3.41300E 03, 3.42557E 03,
265 3.43814E 03, 3.45070E 03, 3.46327E 03, 3.47584E 03, 3.48840E 03, 3.50097E 03,
266 3.51354E 03, 3.52610E 03, 3.53867E 03, 3.55124E 03, 3.56380E 03, 3.57637E 03,
267 3.58894E 03, 3.60150E 03, 3.61407E 03, 3.62664E 03, 3.63920E 03, 3.65177E 03,
268 3.66434E 03, 3.67690E 03, 3.68947E 03, 3.70204E 03, 3.71460E 03, 3.72717E 03,
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272 3.96594E 03, 3.97850E 03, 3.99107E 03, 4.00364E 03, 4.01620E 03, 4.02877E 03,
273 4.04134E 03, 4.05390E 03, 4.06647E 03, 4.07904E 03, 4.09160E 03, 4.10417E 03,
274 4.11674E 03, 4.12930E 03, 4.14187E 03, 4.15444E 03, 4.16700E 03, 4.17957E 03,
275 4.19214E 03, 4.20470E 03, 4.21727E 03, 4.22984E 03, 4.24240E 03, 4.25497E 03,
276 4.26754E 03, 4.28010E 03, 4.29267E 03, 4.30524E 03, 4.31780E 03, 4.33037E 03,
277 4.34294E 03, 4.35550E 03, 4.36807E 03, 4.38064E 03, 4.39320E 03, 4.40577E 03,
278 4.41834E 03, 4.43090E 03, 4.44347E 03, 4.45604E 03, 4.46860E 03, 4.48117E 03,
279 4.49374E 03, 4.50630E 03, 4.51887E 03, 4.53144E 03, 4.54400E 03, 4.55657E 03,
280 4.56914E 03, 4.58170E 03, 4.59427E 03, 4.60684E 03, 4.61940E 03, 4.63197E 03,
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282 4.71994E 03, 4.73250E 03, 4.74507E 03, 4.75764E 03, 4.77020E 03, 4.78277E 03,
283 4.79534E 03, 4.80790E 03, 4.82047E 03, 4.83304E 03, 4.84560E 03, 4.85817E 03,
284 4.87074E 03, 4.88330E 03, 4.89587E 03, 4.90844E 03, 4.92100E 03, 4.93357E 03,
285 4.94614E 03, 4.95870E 03, 4.97127E 03, 4.98384E 03, 4.99640E 03, 5.00897E 03,
286 5.02154E 03, 5.03410E 03, 5.04667E 03, 5.05924E 03, 5.07180E 03, 5.08437E 03,
287 5.09694E 03, 5.10950E 03, 5.12207E 03, 5.13464E 03, 5.14720E 03, 5.15977E 03,
288 5.17234E 03, 5.18490E 03, 5.19747E 03, 5.21004E 03, 5.22260E 03, 5.23517E 03,
289 5.24774E 03, 5.26030E 03, 5.27287E 03, 5.28544E 03, 5.29800E 03, 5.31057E 03,
290 5.32314E 03, 5.33570E 03, 5.34827E 03, 5.36084E 03, 5.37340E 03, 5.38597E 03,
291 5.39854E 03, 5.41110E 03, 5.42367E 03, 5.43624E 03, 5.44880E 03, 5.46137E 03,
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293 5.54934E 03, 5.56190E 03, 5.57447E 03, 5.58704E 03, 5.59960E 03, 5.61217E 03,
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295 5.69914E 03, 5.71170E 03, 5.72427E 03, 5.73684E 03, 5.74940E 03, 5.76197E 03,
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299 5.99974E 03, 6.01230E 03, 6.02487E 03, 6.03744E 03, 6.05000E 03, 6.06257E 03,
300 6.07514E 03, 6.08770E 03, 6.09927E 03, 6.11184E 03, 6.12440E 03, 6.13697E 03,
301 6.14954E 03, 6.16210E 03, 6.17467E 03, 6.18724E 03, 6.19980E 03, 6.21237E 03,
302 6.22494E 03, 6.23750E 03, 6.25007E 03, 6.26264E 03, 6.27520E 03, 6.28777E 03,
303 6.29934E 03, 6.31190E 03, 6.32447E 03, 6.33704E 03, 6.34960E 03, 6.36217E 03,
304 6.37474E 03, 6.38730E 03, 6.39987E 03, 6.41244E 03, 6.42500E 03, 6.43757E 03,
305 6.45014E 03, 6.46270E 03, 6.47527E 03, 6.48784E 03, 6.50040E 03, 6.51297E 03,
306 6.52554E 03, 6.53810E 03, 6.55067E 03, 6.56324E 03, 6.57580E 03, 6.58837E 03,
307 6.59994E 03, 6.61250E 03, 6.62507E 03, 6.63764E 03, 6.65020E 03, 6.66277E 03,
308 6.67534E 03, 6.68790E 03, 6.69947E 03, 6.71204E 03, 6.72460E 03, 6.73717E 03,
309 6.74974E 03, 6.76230E 03, 6.77487E 03, 6.78744E 03, 6.79940E 03, 6.81197E 03,
310 6.82454E 03, 6.83710E 03, 6.84967E 03, 6.86224E 03, 6.87480E 03, 6.88737E 03,
311 6.89994E 03, 6.91250E 03, 6.92507E 03, 6.93764E 03, 6.95020E 03, 6.96277E 03,
312 6.97534E 03, 6.98790E 03, 6.99947E 03, 7.01204E 03, 7.02460E 03, 7.03717E 03,
313 7.04974E 03, 7.06230E 03, 7.07487E 03, 7.08744E 03, 7.09940E 03, 7.11197E 03,
314 7.12454E 03, 7.13710E 03, 7.14967E 03, 7.16224E 03, 7.17480E 03, 7.18737E 03,
315 7.19994E 03, 7.21250E 03, 7.22507E 03, 7.23764E 03, 7.25020E 03, 7.26277E 03,
316 7.27534E 03, 7.28790E 03, 7.29947E 03, 7.31204E 03, 7.32460E 03, 7.33717E 03,
317 7.34974E 03, 7.36230E 03, 7.37487E 03, 7.38744E 03, 7.39940E 03, 7.41197E 03,
318 7.42454E 03, 7.43710E 03, 7.44967E 03, 7.46224E 03, 7.47480E 03, 7.48737E 03,
319 7.49994E 03, 7.51250E 03, 7.52507E 03, 7.53764E 03, 7.55020E 03, 7.56277E 03,
320 7.57534E 03, 7.58790E 03, 7.59947E 03, 7.61204E 03, 7.62460E 03, 7.63717E 03,
321 7.64974E 03, 7.66230E 03, 7.67487E 03, 7.68744E 03, 7.69940E 03, 7.71197E 03,
322 7.72454E 03, 7.73710E 03, 7.74967E 03, 7.76224E 03, 7.77480E 03, 7.78737E 03,
323 7.79994E 03, 7.81250E 03, 7.82507E 03, 7.83764E 03, 7.85020E 03, 7.86277E 03,
324 7.87534E 03, 7.88790E 03, 7.89947E 03, 7.91204E 03, 7.92460E 03, 7.93717E 03,
325 7.94974E 03, 7.96230E 03, 7.97487E 03, 7.98744E 03, 7.99940E 03, 8.01197E 03,
326 8.02454E 03, 8.03710E 03, 8.04967E 03, 8.06224E 03, 8.07480E 03, 8.08737E 03,
327 8.09994E 03, 8.11250E 03, 8.12507E 03, 8.13764E 03, 8.15020E 03, 8.16277E 03,
328 8.17534E 03, 8.18790E 03, 8.19947E 03, 8.21204E 03, 8.22460E 03, 8.23717E 03,
329 8.24974E 03, 8.26230E 03, 8.27487E 03, 8.28744E 03, 8.29940E 03, 8.31197E 03,
330 8.32454E 03, 8.33710E 03, 8.34967E 03, 8.36224E 03, 8.37480E 03, 8.38737E 03,
331 8.39994E 03, 8.41250E 03, 8.42507E 03, 8.43764E 03, 8.45020E 03, 8.46277E 03,
332 8.47534E 03, 8.48790E 03, 8.49947E 03, 8.51204E 03, 8.52460E 03, 8.53717E 03,
333 8.54974E 03, 8.56230E 03, 8.57487E 03, 8.58744E 03, 8.59940E 03, 8.61197E 03,
334 8.62454E 03, 8.63710E 03, 8.64967E 03, 8.66224E 03, 8.67480E 03, 8.68737E 03,
335 8.69994E 03, 8.71250E 03, 8.72507E 03, 8.73764E 03, 8.75020E 03, 8.76277E 03,
336 8.77534E 03, 8.78790E 03, 8.79947E 03, 8.81204E 03, 8.82460E 03, 8.83717E 03,
337 8.84974E 03, 8.86230E 03, 8.87487E 03, 8.88744E 03, 8.89940E 03, 8.91197E 03,
338 8.92454E 03, 8.93710E 03, 8.94967E 03, 8.96224E 03, 8.97480E 03, 8.98737E 03,
339 8.99994E 03, 9.01250E 03, 9.02507E 03, 9.03764E 03, 9.05020E 03, 9.06277E 03,
340 9.07534E 03, 9.08790E 03, 9.09947E 03, 9.11204E 03, 9.12460E 03, 9.13717E 03,
341 9.14974E 03, 9.16230E 03, 9.17487E 03, 9.18744E 03, 9.19940E 03, 9.21197E 03,
342 9.22454E 03, 9.23710E 03, 9.24967E 03, 9.26224E 03, 9.27480E 03, 9.28737E 03,
343 9.29994E 03, 9.31250E 03, 9.32507E 03, 9.33764E 03, 9.35020E 03, 9.36277E 03,
344 9.37534E 03, 9.38790E 03, 9.39947E 03, 9.41204E 03, 9.42460E 03, 9.43717E 03,
345 9.44974E 03, 9.46230E 03, 9.47487E 03, 9.48744E 03, 9.49940E 03, 9.51197E 03,
346 9.52454E 03, 9.53710E 03, 9.54967E 03, 9.56224E 03, 9.57480E 03, 9.58737E 03,
347 9.59994E 03, 9.61250E 03, 9.62507E 03, 9.63764E 03, 9.65020E 03, 9.66277E 03,
348 9.67534E 03, 9.68790E 03, 9.69947E 03, 9.71204E 03, 9.72460E 03, 9.73717E 03,
349 9.74974E 03, 9.76230E 03, 9.77487E 03, 9.78744E 03, 9.79940E 03, 9.81197E 03,
350 9.82454E 03, 9.83710E 03, 9.84967E 03, 9.86224E 03, 9.87480E 03, 9.88737E 03,
351 9.89994E 03, 9.91250E 03, 9.92507E 03, 9.93764E 03, 9.95020E 03, 9.96277E 03,
352 9.97534E 03, 9.98790E 03, 9.99947E 03, 10.01204E 03, 10.02460E 03, 10.03717E 03,
353 10.04974E 03, 10.06230E 03, 10.07487E 03, 10.08744E 03, 10.09940E 03, 10.11197E 03,
354 10.12454E 03, 10.13710E 03, 10.14967E 03, 10.16224E 03, 10.17480E 03, 10.18737E 03,
355 10.19994E 03, 10.21250E 03, 10.22507E 03, 10.23764E 03, 10.25020E 03, 10.26277E 03,
356 10.27534E 03, 10.28790E 03, 10.29947E 03, 10.31204E 03, 10.32460E 03, 10.33717E 03,
357 10.34974E 03, 10.36230E 03, 10.37487E 03, 10.38744E 03, 10.39940E 03, 10.41197E 03,
358 10.42454E 03, 10.43710E 03, 10.44967E 03, 10.46224E 03, 10.47480E 03, 10.48737E 03,
359 10.49994E 03, 10.51250E 03, 10.52507E 03, 10.53764E 03, 10.55020E 03, 10.56277E 03,
360 10.57534E 03, 10.58790E 03, 10.59947E 03, 10.61204E 03, 10.62460E 03, 10.63717E 03,
361 10.64974E 03, 10.66230E 03, 10.67487E 03, 10.68744E 03, 10.69940E 03, 10.71197E 03,
362 10.72454E 03, 10.73710E 03, 10.74967E 03, 10.76224E 03, 10.77480E 03, 10.78737E 03,
363 10.79994E 03, 10.81250E 03, 10.82507E 03, 10.83764E 03, 10.85020E 03, 10.86277E 03,
364 10.87534E 03, 10.88790E 03, 10.89947E 03, 10.91204E 03, 10.92460E 03, 10.93717E 03,
365 10.94974E 03, 10.96230E 03, 10.97487E 03, 10.98744E 03, 10.99940E 03, 11.01197E
```

The following is a brief description of each control card listed above.

Card 1

This is the run card of which two are required for each run on the MSFC/U1108 computer. The user should insert his name in space A , his bin number in space B , an estimate of the run time (recommended $\approx$ 10 minutes) in space C , estimated printer page output ($\approx$ 500) in space D and an estimate of the punched cards output (if any is desired) in space E . In addition, it should be remembered that SRB-IIID requires 40K words of core storage which should be entered on run card number 2 (green card).

Card 2

This card is optional and causes the run date and page numbers to be printed at the start of each page of printed output.

Card 3

The third card defines the filename (SRB3D1) and tape number (07994) which contain the SRB-IIID program. Tape number 07994 should also be noted in the appropriate space on run card No. 2.

Card 4

Card 4 releases the temporary program file (TPF\$) storage area.

Card 5

The fifth card redefines the TPF\$ storage and expands it for the SRB-IIID program.

Card 6

This card causes the tape to be rewound to the beginning of the SRB3D1 program file.

Card 7

Card 7 reads the entire contents of SRB3D1 into TPF\$.

Card 8

Card 8 causes the tape containing SRB3D1 to be rewound and releases the tape unit used for this file.

Card 9

This card signifies that the data element CARDZ is going to be updated, and that a listing of the entire element including updates, will be produced. To update this data element, the user is referred to Figure 3-3 which contains the element listing. Two examples of how this element could be updated are shown below.

- (1) Change the value of an input variable card currently on the element file.

```
@ELT,UL CARDZ  
-29,29  
KPLANE = 16,
```

- (2) Add values not contained in CARDZ

```
@ELT,UL CARDZ  
-23  
RI(10,6) = 31.385,
```

Card 10

The tenth card causes the absolute element of SRB-IIID to be executed.

Card 11

Card 11 causes the updated data element (CARDZ) to be added to the run-stream.

Card 12

This card signifies that the end of the program deck has been reached. Two of these cards are required on each deck.

3.4 PROGRAM PRINTED OUTPUT

The following paragraphs describe the SRB-IIID program output.

3.4.1 Input Data and Initial Values Printout

The input data and initial values printouts are standard forms of output for every SRB-IIID run. The input data printout duplicates the data element

(including updates) and is done on a case by case basis. The initial values printout, as shown in Figure 3-4, lists values for constants, indicators and the inert mass schedule for the case to be executed. In addition to these items, the initial cylindrical section geometry is listed for each sector being simulated at each reference plane, as are geometry values input and calculated in the end regions.

3.4.2 Motor Performance Data Printout

Motor performance data are printed at the end of each computation time step. This printout, as shown in Figure 3-5, is identical to that provided for SRB-II with the exception that the total vacuum specific impulse (Isp) parameter has been added for SRB-IIID,

3.4.3 Increment Dividing Plane Data Printout

The increment dividing plane printout follows the motor performance data printout at each time step and is not optional. This print provides the user with detailed performance data of the mass addition regions in the cylindrical section as well as the head and aft ends (see Figure 3-6). The following list defines the parameters given for each increment dividing plane.

MASS ADDITION REGIONS	The longitudinal location of the downstream increment dividing plane
PO	Total pressure
P	Static pressure
T	Static temperature
U	Gas velocity
M	Mach number
LP	Port perimeter - (Sum of each sector's contribution)
AP	Port area - (Sum of each sector's contribution)
WDOT	Discharge mass flow rate (sum of each sector's contribution)
DWDOT	Generated mass flow rate - (Sum of each sector's contribution)
DW/DT	Mass buildup in region - (Sum of each sector's contribution)
RB	Sector/IDP average burn rate
TAU	Sector/IDP average burn distance.

PROGRAM CONSTANTS

... TOTAL INERT MASS(MITUT) = 7358.3000

3-17

CYLINDRICAL SECTION INITIAL GEOMETRY

SECTION FUEL RADIUS (IN)

SECTION •	1 ••	2 ••	3 ••	4 ••	5 ••	6 ••	7 ••	8 •
RP								
1	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840
2	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840
3	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840	72.3840
4	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140
5	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
6	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
7	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
8	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140	72.3140
9	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
10	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
11	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140	72.2140
12	72.1800	72.1800	72.1800	72.1800	72.1800	72.1800	72.1800	72.1800
13	72.1300	72.1300	72.1300	72.1300	72.1300	72.1300	72.1300	72.1300
14	71.3440	71.3440	71.3440	71.3440	71.3440	71.3440	71.3440	71.3440
15	71.1390	71.1390	71.1390	71.1390	71.1390	71.1390	71.1390	71.1390

CYLINDRICAL SECTION INITIAL GEOMETRY

SECTION PORT RADIUS (IN)

SECTION •	1 ••	2 ••	3 ••	4 ••	5 ••	6 ••	7 ••	8 •
RP								
1	28.7270	28.7270	28.7270	28.7270	28.7270	28.7270	28.7270	28.7270
2	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100
3	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100	29.1100
4	28.9800	28.9800	28.9800	28.9800	28.9800	28.9800	28.9800	28.9800
5	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500
6	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850
7	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850
8	28.9500	28.9500	28.9500	28.9500	28.9500	28.9500	28.9500	28.9500
9	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500
10	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850
11	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850	31.1850
12	30.9100	30.9100	30.9100	30.9100	30.9100	30.9100	30.9100	30.9100
13	31.5670	31.5670	31.5670	31.5670	31.5670	31.5670	31.5670	31.5670
14	40.3200	40.3200	40.3200	40.3200	40.3200	40.3200	40.3200	40.3200
15	41.6800	41.6800	41.6800	41.6800	41.6800	41.6800	41.6800	41.6800

Figure 3-4. SAMPLE SRB-IIID INITIAL VALUES PRINTOUT (Continued)

CYLINDRICAL SECTION INITIAL GEOMETRY

SECTOR PORT AREA (APMTSL)

SECTION •	1	••	2	••	3	••	4	••	5	••	6	••	7	••	8	•
RP																
1	324.0750		324.0750		324.0750		324.0750		324.0750		324.0750		324.0750		324.0750	
2	332.7750		332.7750		332.7750		332.7750		332.7750		332.7750		332.7750		332.7750	
3	332.7750		332.7750		332.7750		332.7750		332.7750		332.7750		332.7750		332.7750	
4	329.8000		329.8000		329.8000		329.8000		329.8000		329.8000		329.8000		329.8000	
5	371.3250		371.3250		371.3250		371.3250		371.3250		371.3250		371.3250		371.3250	
6	381.9000		381.9000		381.9000		381.9000		381.9000		381.9000		381.9000		381.9000	
7	381.9000		381.9000		381.9000		381.9000		381.9000		381.9000		381.9000		381.9000	
8	329.1250		329.1250		329.1250		329.1250		329.1250		329.1250		329.1250		329.1250	
9	371.3250		371.3250		371.3250		371.3250		371.3250		371.3250		371.3250		371.3250	
10	381.9000		381.9000		381.9000		381.9000		381.9000		381.9000		381.9000		381.9000	
11	381.9000		381.9000		381.9000		381.9000		381.9000		381.9000		381.9000		381.9000	
12	375.2000		375.2000		375.2000		375.2000		375.2000		375.2000		375.2000		375.2000	
13	391.3125		391.3125		391.3125		391.3125		391.3125		391.3125		391.3125		391.3125	
14	638.4125		638.4125		638.4125		638.4125		638.4125		638.4125		638.4125		638.4125	
15	682.2000		682.2000		682.2000		682.2000		682.2000		682.2000		682.2000		682.2000	

CYLINDRICAL SECTION INITIAL GEOMETRY

SECTOR PORT PERIMETER (ALPSEC)

SECTION •	1	••	2	••	3	••	4	••	5	••	6	••	7	••	8	•
RP																
1	22.5625		22.5625		22.5625		22.5625		22.5625		22.5625		22.5625		22.5625	
2	22.8625		22.8625		22.8625		22.8625		22.8625		22.8625		22.8625		22.8625	
3	31.0625		31.0625		31.0625		31.0625		31.0625		31.0625		31.0625		31.0625	
4	22.7625		22.7625		22.7625		22.7625		22.7625		22.7625		22.7625		22.7625	
5	24.8588		24.8588		24.8588		24.8588		24.8588		24.8588		24.8588		24.8588	
6	24.4925		24.4925		24.4925		24.4925		24.4925		24.4925		24.4925		24.4925	
7	46.2375		46.2375		46.2375		46.2375		46.2375		46.2375		46.2375		46.2375	
8	22.7375		22.7375		22.7375		22.7375		22.7375		22.7375		22.7375		22.7375	
9	24.1512		24.1512		24.1512		24.1512		24.1512		24.1512		24.1512		24.1512	
10	24.4925		24.4925		24.4925		24.4925		24.4925		24.4925		24.4925		24.4925	
11	43.6750		43.6750		43.6750		43.6750		43.6750		43.6750		43.6750		43.6750	
12	24.2750		24.2750		24.2750		24.2750		24.2750		24.2750		24.2750		24.2750	
13	24.7925		24.7925		24.7925		24.7925		24.7925		24.7925		24.7925		24.7925	
14	31.6675		31.6675		31.6675		31.6675		31.6675		31.6675		31.6675		31.6675	
15	32.7350		32.7350		32.7350		32.7350		32.7350		32.7350		32.7350		32.7350	

Figure 3-4. SAMPLE SRB-IIID INITIAL VALUES PRINTOUT (Continued)


```

HEAD END
DEI 4.2000000+01 RE 1.0000000+00 AUFH 9.0000000+01 MEND 1 DELH 2.2810000+01
HEI ALFH 2.1000000+01 ALFH 1.2764448+00 RE2 2.1000000+01 HEI 6.9270798+01 HE0 HEK 6.9270798+01
VLEO 0.0000000 VCE 7.9213007+05 TAUU 0.6248240+01 TAUU 0.0000000 CDE 0.0000000 CCE 2.0957773+04 0.0000000
CDE 0.0000000 CCE 0.0000000 CCE 0.0000000 CCE 0.0000000 CCE 0.0000000
H.9922648+05 0.4000000+01 9.2423789+06 2.0957773+04

NOZZLE END
DEI 4.0000000+01 RE 1.0000000+00 AUFH 9.0000000+01 MEND 2 DELH 2.2810000+01
HEI ALFH 2.1000000+01 ALFH 1.2764448+00 RE2 2.1000000+01 HEI 6.9270798+01 HE0 HEK 6.9270798+01
VLEO 0.0000000 VCE 7.9213007+05 TAUU 0.6248240+01 TAUU 0.0000000 CDE 0.0000000 CCE 2.0957773+04 0.0000000
CDE 0.0000000 CCE 0.0000000 CCE 0.0000000 CCE 0.0000000 CCE 0.0000000
H.9922648+05 0.4000000+01 9.2423789+06 2.0957773+04

```

Figure 3-4. SAMPLE SRB-IIID INITIAL VALUES PRINTOUT (Concluded)

IGNITION TIME, TIME (S)

91.500000

PARAMETER DESCRIPTION (UNITS)	PROGRAM NOMENCLATURE	INTERNATIONAL	ENGLISH
MOTOR PARAMETERS:			
TOTAL DELIVERED THRUST (N,LBF)	FTDEL	10725797.	2456216.8
TOTAL VACUUM THRUST (N,LBF)	FTVAC	11005267.	2474082.8
THRUST CONTRIBUTION OF INERTS (N,LBF)	FI	50062.804	11254.566
DELIVERED TOTAL IMPULSE (N*S,LBF*S)	SRMOT	.92238696*09	.20736084*09
TOTAL VACUUM SPECIFIC IMPULSE (S,S)	TISP	256.86414	256.86414
VACUUM TOTAL IMPULSE (N*S,LBF*S)	SRMVT	.97139043*09	.21837726*09
THRUST COEFFICIENT	CF	1.4248756	1.6248756
GRAIN DISCHARGE MASS FLOWRATE (KG/S,LBM/S)	MDOT	4342.0758	9572.6385
FLOWRATE INTEGRAL (KG,LBM)	SDUTN	382227.54	842667.48
INERT MASS FLOWRATE (KG/S,LBM/S)	MIF	26.868344	59.234558
INERT MASS REMAINING (KG,LBM)	MIR	1075.3748	2370.7756
TOTAL BURN AREA (M**2,IN**2)	ABTOT	263.74333	409112.99
TOTAL PROPELLANT VOLUME (M**3,IN**3)	VF	70.802714	4320646.7
PROPELLANT MASS REMAINING (KG,LBM)	WF	123299.57	271829.03
TOTAL GAS MASS (KG,LBM)	WGTOT	1258.3258	2774.1335
RATIO OF SPECIFIC HEATS	GAMA	1.1597544	1.1597544
MOLECULAR WEIGHT OF GAS (KG/MOLE,LBM/MOLE)	ANW	12.853033	28.336088
CHARACTERISTIC EXHAUST VELOCITY (M/S,FT/S)	CSTAR	1559.8547	5117.6334
MAXIMUM CHAMBER MACH NUMBER	AMPN	.94623807-01	.94623807-01
HEAD END PARAMETERS:			
TOTAL PRESSURE (N/M**2,LBF/IN**2)	PH	.43737724*09	634.36207
PRESSURE INTEGRAL (N*S/M**2,LBF*S/IN**2)	SPHUT	.40999182*11	59464.287
BURN AREA (M**2,IN**2)	ANH	6.9763955	10813.435
BURN RATE (M/S,IN/S)	RBZ(1)	.93789346*02	.36924940
DISTANCE BURNED (M,IN)	TAUZ(1)	.79606555	31.341164
PROPELLANT VOLUME (M**3,IN**3)	VFH	1.4795631	95288.482
GAS VOLUME (M**3,IN**3)	VPH	53.624269	3272353.7
GAS STATIC TEMPERATURE (DEG K,DEG R)	PRNT(1,3)	3402.2608	6124.0694
CYLINDRICAL SECTION PARAMETERS:			
RADIAL BURN AREA (M**2,IN**2)	ABCYL	256.96694	398279.55
SEGMENT FACE BURN AREA (M**2,IN**2)	ABSLT	.00000000	.00000000
PROPELLANT VOLUME (M**3,IN**3)	VFCYL	69.321250	4230242.2
GAS VOLUME (M**3,IN**3)	VP	218.67090	13344117.
AFT END PARAMETERS:			
TOTAL PRESSURE NOZ ENT (N/M**2,LBF/IN**2)	PUN	.42951891*09	622.74452
PRESSURE INTEGRAL (N*S/M**2,LBF*S/IN**2)	SPONOT	.38787616*11	56256.681
BURN AREA (M**2,IN**2)	AAN	.00000000	.00000000
BURN RATE, REGION A (M/S,IN/SEC)	RBZ(NI*1,1)	.93651086*02	.36870506
BURN RATE, REGION B (M/S,IN/SEC)	RBZ(NI*2,1)	.93570785*02	.36838892
DISTANCE BURNED, REGION A (M,IN)	TAUZ(NI*1,1)	.74828400	29.460000
DISTANCE BURNED, REGION B (M,IN)	TAUZ(NI*2,1)	.52501800	20.670000
PROPELLANT VOLUME (M**3,IN**3)	VFN	.19323254*02	116.08702
GAS VOLUME (M**3,IN**3)	VPH	17.047527	1040333.9
GAS STATIC TEMP, NOZ ENT (DEG K,DEG R)	PRNT(NI*2,3)	3400.7742	6121.3936
PORT AREA, NOZ ENT (M**2,IN**2)	AZA	10.208839	15823.733
NOZZLE PARAMETERS:			
THROAT AREA (M**2,IN**2)	AT	1.5768785	2444.1664
EXPANSION RATIO	EPR	6.8163242	6.8163242
PRESSURE RATIO	PEPO	.23055702*01	.23055702*01
MISCELLANEOUS PARAMETERS:			
ANISOTROPIC BURN RATE COEFFICIENT	AKRST	.37810250*01	.37810250*01
NUMBER OF PRESSURE ITERATIONS	ANLOPS	3.0000000	3.0000000

Figure 3-5. SAMPLE MOTOR PERFORMANCE DATA PRINTOUT

INCREMENT DIVIDING PLANE DATA:

MASS ADDITION REGIONS	P0	P	PSIA	DEG. R	U	H	LP	AP	WDOT	DWDT	DW/DT	RB	TAU	RATO	TAUTO
	PSIA				FT/SEC		INCHES	SQ. IN.	LB/SEC	LN/SEC	LB/SEC	IN/SEC	IN.	IN/SEC	IN.
FONE	634.34	634.35	6124.07	12.03		.003	377.36	11326.98	250.67	253.22	-5.49	.3690	31.341	.0000	.0000
15.000	634.35	634.34	6124.06	10.17		.005	377.62	11343.41	371.24	132.58	.01	.3690	31.306	.0000	.0000
40.000	634.35	634.33	6124.05	24.29		.007	377.88	11359.83	523.91	132.67	.01	.3690	31.332	.0000	.0000
45.000	634.34	634.31	6124.04	30.40		.009	378.14	11376.22	656.66	132.77	.01	.3690	31.297	.0000	.0000
40.000	634.33	634.29	6124.02	36.50		.010	378.41	11392.58	789.50	132.86	.01	.3690	31.292	.0000	.0000
75.000	634.32	634.27	6124.00	42.59		.012	378.67	11408.93	922.44	132.95	.01	.3690	31.287	.0000	.0000
90.000	634.30	634.23	6123.98	48.66		.014	378.93	11425.24	1055.46	133.04	.01	.3690	31.282	.0000	.0000
105.000	634.29	634.20	6123.96	54.72		.015	379.19	11441.54	1188.57	133.12	.01	.3690	31.277	.0000	.0000
116.761	634.27	634.17	6123.94	59.47		.017	379.49	11454.30	1293.01	104.44	.01	.3690	31.272	.0000	.0000
116.771	634.27	634.17	6123.94	59.65		.017	378.41	11419.51	1293.01	.00	.00	.3690	31.273	.0000	.0000
131.771	634.25	634.13	6123.91	65.37		.019	380.60	11410.40	1415.76	122.74	.00	.3690	31.273	.0000	.0000
143.919	634.24	634.09	6123.88	70.27		.020	378.57	11403.95	1520.87	105.11	.00	.3690	31.266	.0000	.0000
158.919	634.21	634.04	6123.85	76.10		.022	379.50	11451.52	1653.97	133.11	.01	.3690	31.260	.0000	.0000
173.919	634.18	633.98	6123.81	81.90		.023	380.43	11499.81	1787.38	133.43	.01	.3690	31.254	.0000	.0000
188.919	634.15	633.92	6123.77	87.67		.025	381.35	11547.90	1921.12	133.75	.01	.3689	31.248	.0000	.0000
203.919	634.12	633.88	6123.73	93.41		.026	382.28	11595.80	2055.18	134.07	.01	.3689	31.242	.0000	.0000
218.919	634.08	633.79	6123.69	99.12		.028	383.21	11643.50	2189.56	134.39	.01	.3689	31.236	.0000	.0000
233.919	634.05	633.72	6123.64	104.80		.030	384.13	11691.01	2325.26	134.71	.01	.3689	31.230	.0000	.0000
248.919	634.01	633.65	6123.60	110.46		.031	385.06	11738.33	2459.27	135.03	.01	.3689	31.224	.0000	.0000
263.919	633.97	633.57	6123.55	116.08		.033	385.99	11785.46	2594.61	135.35	.01	.3689	31.218	.0000	.0000
278.919	633.92	633.49	6123.49	121.68		.034	386.91	11832.39	2730.27	135.66	.01	.3688	31.211	.0000	.0000
293.919	633.88	633.40	6123.44	127.26		.036	387.84	11879.13	2866.25	135.98	.01	.3688	31.205	.0000	.0000
308.919	633.83	633.31	6123.38	132.83		.038	388.77	11925.68	3002.54	136.30	.01	.3688	31.198	.0000	.0000
323.919	633.78	633.21	6123.32	138.33		.039	389.69	11972.93	3139.15	136.62	.01	.3688	31.191	.0000	.0000
338.919	633.72	633.11	6123.26	143.83		.041	390.62	12018.19	3276.08	136.94	.01	.3688	31.184	.0000	.0000
353.919	633.67	633.01	6123.20	149.31		.042	391.55	12064.16	3413.33	137.25	.00	.3687	31.178	.0000	.0000
368.919	633.61	632.91	6123.14	154.76		.044	392.47	12109.94	3550.89	137.57	.00	.3687	31.171	.0000	.0000
383.919	633.55	632.80	6123.07	160.19		.045	393.40	12155.52	3688.78	137.89	.00	.3687	31.164	.0000	.0000
398.919	633.49	632.68	6123.00	165.60		.047	394.33	12200.91	3826.97	138.20	.00	.3687	31.156	.0000	.0000
403.048	633.47	632.65	6122.98	167.09		.047	394.58	12213.37	3865.07	138.17	.00	.3686	31.149	.0000	.0000
418.048	633.42	632.53	6122.90	173.18		.049	392.72	12207.39	4003.18	138.11	.00	.3686	31.147	.0000	.0000
427.051	633.38	632.46	6122.85	176.82		.050	391.60	12203.53	4085.75	82.58	.00	.3686	31.141	.0000	.0000
477.061	633.34	632.76	6123.31	139.89		.040	95.58	15410.66	4085.76	.00	.00	.3686	31.166	.0000	.0000
482.061	633.47	632.73	6123.09	158.68		.045	212.50	13774.29	4140.08	54.05	.00	.3687	31.167	.0000	.0000
487.061	633.68	632.67	6122.72	185.50		.053	329.43	12054.23	4235.28	45.08	.00	.3687	31.139	.0000	.0000
463.204	633.79	632.62	6122.51	199.77		.057	377.32	11327.96	4286.07	50.78	.00	.3687	31.098	.0000	.0000
478.204	633.71	632.47	6122.42	205.33		.058	378.09	11344.14	4416.56	132.50	.01	.3687	31.077	.0000	.0000
493.204	633.63	632.32	6122.33	210.88		.060	378.47	11400.19	4551.24	132.69	.01	.3686	31.068	.0000	.0000
508.204	633.55	632.17	6122.24	216.40		.061	379.04	11436.11	4684.11	132.88	.01	.3686	31.059	.0000	.0000
523.204	633.46	632.01	6122.14	221.90		.063	379.62	11471.90	4817.17	133.07	.01	.3686	31.049	.0000	.0000
538.204	633.37	631.85	6122.05	227.39		.064	380.19	11507.56	4950.42	133.26	.01	.3685	31.039	.0000	.0000
553.204	633.28	631.68	6121.95	232.86		.066	380.77	11543.10	5083.86	133.45	.01	.3685	31.030	.0000	.0000
568.204	633.19	631.52	6121.85	238.31		.068	381.35	11578.50	5217.49	133.64	.01	.3685	31.020	.0000	.0000
583.204	633.09	631.34	6121.74	243.74		.069	381.92	11613.77	5351.31	133.83	.01	.3684	31.010	.0000	.0000
598.204	632.99	631.17	6121.64	249.16		.071	382.50	11649.91	5485.32	134.02	.01	.3684	31.000	.0000	.0000
613.204	632.89	630.99	6121.53	254.55		.072	383.07	11683.92	5619.51	134.20	.01	.3684	30.990	.0000	.0000

Figure 3-6. SAMPLE INCREMENT DIVIDING PLANE PRINTOUT

628-204	632-79	630-81	6121-42	259.94	.074	303-65	11718-80	5753-90	134-39	.01	.3683	30-980	.0000	.0000
643-204	632-69	630-62	6121-31	265.30	.075	304-22	11753-54	5886-47	134-58	.01	.3683	30-970	.0000	.0000
658-204	632-58	630-43	6121-20	270.45	.077	304-80	11780-16	6023-23	134-77	.01	.3682	30-960	.0000	.0000
673-204	632-47	630-24	6121-09	275.99	.078	305-37	11822-65	6158-18	134-95	.01	.3682	30-949	.0000	.0000
688-204	632-36	630-04	6120-97	281.31	.080	305-95	11857-51	6293-31	135-14	.01	.3682	30-939	.0000	.0000
703-204	632-25	629-84	6120-85	286.62	.081	306-52	11891-24	6420-63	135-32	.00	.3681	30-929	.0000	.0000
718-204	632-13	629-63	6120-73	291.91	.083	307-10	11925-34	6564-14	135-51	.00	.3681	30-918	.0000	.0000
726-191	632-07	629-52	6120-67	294.73	.083	308-71	11943-44	6636-37	72-23	.00	.3680	30-908	.0000	.0000
741-191	631-91	629-31	6120-60	297.80	.084	309-39	12066-30	6772-40	136-04	.00	.3680	30-902	.0000	.0000
746-336	631-86	629-24	6120-57	298.86	.085	390-67	12108-13	6819-21	46-82	.00	.3679	30-897	.0000	.0000
746-346	631-77	630-03	6121-75	243.58	.069	186-08	14840-05	6819-22	.00	.00	.3681	30-945	.0000	.0000
761-346	631-94	629-95	6121-38	261.85	.074	248-58	13960-34	6895-56	76-14	.00	.3681	30-946	.0000	.0000
776-346	632-19	629-83	6120-92	283.54	.080	311-07	13077-46	6993-73	98-03	.00	.3681	30-921	.0000	.0000
791-346	632-48	629-67	6120-32	308.41	.088	373-57	12191-42	7113-70	119-92	.00	.3681	30-892	.0000	.0000
794-831	632-54	629-62	6120-15	316.12	.090	388-09	11985-11	7144-69	30-99	.00	.3680	30-856	.0000	.0000
809-831	632-41	629-40	6120-04	320.61	.091	389-07	12046-52	7280-80	136-13	.00	.3680	30-850	.0000	.0000
824-831	632-27	629-17	6119-93	325.09	.092	390-05	12107-51	7417-23	136-44	.00	.3680	30-841	.0000	.0000
839-831	632-13	628-94	6119-81	329.55	.093	391-02	12168-09	7553-99	136-76	.00	.3679	30-831	.0000	.0000
854-781	631-98	628-71	6119-70	333.98	.095	392-00	12228-05	7690-62	136-62	.00	.3679	30-821	.0000	.0000
869-781	631-67	628-47	6119-80	330.23	.094	396-43	12593-74	7828-63	138-01	.00	.3678	30-812	.0000	.0000
884-781	631-38	628-24	6119-88	327-06	.093	400-87	12947-23	7968-17	139-53	.00	.3677	30-817	.0000	.0000
899-781	631-10	628-02	6119-95	324.42	.092	405-30	13288-51	8109-23	141-05	.00	.3676	30-822	.0000	.0000
914-781	630-84	627-80	6120-00	322.76	.091	409-74	13617-58	8251-81	142-57	.00	.3675	30-824	.0000	.0000
929-781	630-59	627-58	6120-04	320.55	.091	414-17	13934-45	8395-90	144-08	.00	.3674	30-826	.0000	.0000
944-781	630-36	627-37	6120-08	319.24	.090	418-61	14239-12	8541-52	145-60	.00	.3674	30-826	.0000	.0000
959-781	630-13	627-17	6120-10	318.31	.090	423-04	14531-58	8688-67	147-12	.00	.3673	30-826	.0000	.0000
974-781	629-92	626-96	6120-11	317.73	.090	427-48	14811-84	8837-37	148-67	.00	.3673	30-826	.0000	.0000
989-781	629-71	626-76	6120-12	317.50	.090	431-91	15079-89	8987-67	150-26	.00	.3675	30-825	.0000	.0000
1004-781	629-51	626-56	6120-12	317.58	.090	436-35	15335-74	9139-64	151-92	.00	.3679	30-823	.0000	.0000
1019-781	629-32	626-36	6120-11	317.97	.090	440-78	15579-38	9293-34	153-66	.00	.3691	30-823	.0000	.0000
1034-781	629-13	626-16	6120-09	318.66	.090	445-22	15810-82	9448-87	155-48	.00	.3691	30-823	.0000	.0000
1040-781	629-05	626-08	6120-08	319.02	.090	446-99	15900-13	9511-73	62-83	.00	.3695	30-822	.0000	.0000
1055-781	629-02	626-01	6120-03	320.94	.091	448-03	15903-59	9570-74	58-90	.00	.3698	30-883	.0000	.0000
1070-781	629-01	626-01	6120-04	320.71	.091	.00	15916-41	9570-98	.00	.00	.3698	29-942	.0000	.0000
1084-171	622-97	595-30	6083-92	986.59	.280	.00	15921-92	9571-32	.00	.00	.3698	29-459	.0000	.0000
AF (A)	622-97	595-30	6083-92	986.59	.280	.00	15823-73	9572-64	.00	.00	.3687	29-460	.0000	.0000
AF (A)	622-95	622-95	6121-39	- .03	.000	.0000	10413-12	.52	.00	.00	.3684	20-870	.0000	.0000

Figure 3-6. SAMPLE INCREMENT DIVIDING PLANE PRINTOUT (Concluded)

If the motor being simulated is segmented, data for the variables listed above will also be included for each slot in the IDP printout. These data are printed for the slot forward and aft interface locations as shown in Figure 3-7.

3.4.4 Diagnostic Data Dumps

The diagnostic data dumps contained in SRB-IIID are the same as those in SRB-II. Users who desire to use those dumps should first consult the SRB-II Users Manual (Reference 2).

3.4.5 Web Burnout Data Printout

When a web burnout occurs in any sector of an increment dividing plane, a statement is printed as shown in Figure 3-8. The contents of this message are described below.

VARIABLE STATEMENT	DEFINITION
WEB BURNOUT INCREMENT LOCATION = XXX.XXX	This is the longitudinal location of the increment dividing plane.
SECTOR NO. = X	This is the sector number where the burnout has occurred.
TAU = XX.XXX	This is the increment dividing plane/sector value of distance burned.
TAUWDP = XX.XXX	This is the increment dividing plane/sector value of the web thickness.
TIME = XX.XX	This is the calculation time point at which the burnout was detected.

In addition to the web burnout statement mentioned above, subroutine PARTBN prints out a message (see Figure 3-8) for sectors of mass addition regions which are partially burned out. The contents of this message are shown below.

TIME = XXX.XX	Time at which PARTBN called
IS = X	Sector number
ZCALC(XXX) = XXX.XX	Downstream increment dividing plane longitudinal location

SLOT INTERFACE LOCATION	P0 PSIA	P PSIA	T DEG. R	U FT/SEC	AP SQ. IN.	DMOOT LB/SEC	AB SQ. IN.	RB IN/SEC	DELTA TAU IN.	WSLOT LB/SEC
FORWARD	1.1676*02	6.3427*02	6.1239*03	4.1393*01	1.6460*04	0.0000	0.0000	0.0000	0.0000	1.2930*03
AFT	1.1677*02	6.3427*02	6.1239*03	4.1393*01	1.6460*04	0.0000	0.0000	0.0000	0.0000	1.2930*03
GAS BUILDUP IN SLOT, DM/DT = -3.0002-04										
FORWARD	4.2705*02	6.3338*02	6.1220*03	1.3171*02	1.6383*04	0.0000	0.0000	0.0000	0.0000	4.0858*03
AFT	4.2706*02	6.3360*02	6.1233*03	1.3166*02	1.6383*04	0.0000	0.0000	0.0000	0.0000	4.0858*03
GAS BUILDUP IN SLOT, DM/DT = -3.0060-04										
FORWARD	7.4634*02	6.3186*02	6.1206*03	2.2086*02	1.6303*04	0.0000	0.0000	0.0000	0.0000	6.8192*03
AFT	7.4635*02	6.3265*02	6.1217*03	2.2084*02	1.6303*04	0.0000	0.0000	0.0000	0.0000	6.8192*03
GAS BUILDUP IN SLOT, DM/DT = -3.0545-04										

Figure 3-7. SAMPLE SLOT PARAMETERS PRINTOUT

WEB BURNOUT INCREMENT LOCATION = 1043.7910	SECTION NO. 2	TAU = 31.0240	TAUWOP = 31.0240	TIME = 81.50
WEB BURNOUT INCREMENT LOCATION = 1043.7910	SECTION NO. 3	TAU = 31.0240	TAUWOP = 31.0240	TIME = 81.50
PARTIAL TIME= 82.00 IS=1 ZCALC(78)=1040.79 ZCALC(77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 5.957 ALP=448.20 ALPHI=446.50				
PARTIAL TIME= 82.00 IS=2 ZCALC(78)=1040.79 ZCALC(77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 5.446 ALP=448.21 ALPHI=446.66				
PARTIAL TIME= 82.00 IS=3 ZCALC(78)=1040.79 ZCALC(77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 5.494 ALP=448.21 ALPHI=446.65				
PARTIAL TIME= 82.00 IS=4 ZCALC(78)=1040.79 ZCALC(77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 6.150 ALP=448.20 ALPHI=446.42				
PARTIAL TIME= 82.00 IS=5 ZCALC(78)=1040.79 ZCALC(77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 1.266 ALP=448.16 ALPHI=447.98				
PARTIAL TIME= 82.00 IS=6 ZCALC(78)=1040.79 ZCALC(77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 1.496 ALP=448.16 ALPHI=447.94				
PARTIAL TIME= 82.00 IS=7 ZCALC(78)=1040.79 ZCALC(77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 1.416 ALP=448.16 ALPHI=447.94				
PARTIAL TIME= 82.00 IS=8 ZCALC(78)=1040.79 ZCALC(77)=1034.78 AINCW=1040.74 AINCHI=1034.78 DELZ= 1.125 ALP=448.17 ALPHI=448.01				

Figure 3-8. SAMPLE WEB BURNOUT PRINT

ZCALC(XXX) = XXX.XX	Upstream increment dividing plane longitudinal location.
AINCW = XXX.XX	New location of downstream limit of sector mass addition region
AINCHI = XXX.XX	New location of upstream limit of sector mass addition region
DELZ = XX.XXX	Distance between AINCW and AINCHI.
ALP = XXX.XX	Total circular perimeter existing at AINCW
ALPHI = XXX.XX	Total circular perimeter existing at AINCHI.

It should be noted that while this message is printed for each sector of the mass addition region which is partially burned out, the values of perimeter (ALP and ALPHI) are not sector values but total perimeters. These values should be divided by the number of sectors being simulated to determine the sector values.

3.5 MAGNETIC TAPE OUTPUT

The SRB-IIID program has three optional magnetic tape outputs. The first two are the internal ballistics data tape written on unit 12, and the internal ballistics plot tape written on unit 13, both of which are discussed in the SRB-II Users Manual. The third tape is one which is set up to generate data specifically for the Shuttle vehicle program and contains the following data written at each computation time step.

- (1) Time from ignition (sec)
- (2) Total vacuum thrust (lbf)
- (3) Total vacuum Isp (sec)
- (4) Thrust coefficient
- (5) Throat area (in.²)
- (6) Nozzle exit area (in.²)
- (7) Nozzle entrance total pressure (psia)
- (8) Inert mass flow rate (lbm/sec)

The writing of this tape is controlled by specifying variable NSTAPE = 1, in the Control Data Package of the input.

3.6 PUNCHED CARD OUTPUT

SRB-IIID will punch performance parameters on cards at the conclusion of each time step by setting the variable NSCARD = 1, in the control data package of the input data. The parameters which are punched on each card are shown below.

- (1) Time from ignition (sec)
- (2) Total vacuum thrust (lbf)
- (3) Total vacuum Isp (sec)
- (4) Head-end total pressure (psia)

When this optional output is selected, the user is reminded to specify card output on his run card and estimate the number of cards to be punched. A nominal value of 200 should be adequate for most cases.

The sample case contained in Volume II will provide the user with a better understanding of the input data and prediction outputs.

Section IV

REFERENCES

1. Solid Rocket Booster Performance Evaluation Model, Volume I - Engineering Description. Boeing Document DCN-1-2-50-23786, September 7, 1974.
2. Solid Rocket Booster Performance Evaluation Model, Volume II - Users Manual. Boeing Document DCN-1-2-50-23786, September 7, 1974.
3. Solid Propellant Rocket Motor Internal Ballistics Computer Program - Program Manual. Boeing Document D2-125286-1, February 28, 1967.